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SECOND QUARTER 1965

JULY 9, 1965

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APOLLO RELIABILITY & QUALITY ASSURANCE OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

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Prepared by

Apollo Reliability and Quality Assurance Office
National Aeronautics and Space Administration
Washington, D.C. 20546

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FOREWORD

Apollo Program Reliability and Quality Assurance Status Reports are prepared quarterly by the Apollo Reliability and Quality Assurance Office for the Apollo Program Director. These reports are based upon an analysis of center/contractor status reports and inputs combined to reflect the status of specific Apollo-Saturn Missions and of the over-all Apollo Reliability and Quality Assurance Program.

The purpose of the report is to document the current reliability and quality assurance status, the requirements to improve the program, and the measurement of effectiveness of the program in attaining Apollo Program mission success and crew safety goals.

To accomplish the stated purpose, reliability and quality assurance status of the Apollo-Saturn 201 Mission and the Apollo-Saturn Manned Lunar Landing Mission has been determined and reported to establish program baselines. Incremental differences between these missions and each of the remaining related missions will be identified and analyzed from a reliability and quality view point in future reports. Future emphasis will be placed on the presentation of trends pertaining to mission success and crew safety performance, and trends pertaining to the degree of effective implementation of the reliability and quality disciplines during the design, fabrication, and test phases that support each mission.

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SECTION 1: INTRODUCTION

This report documents the highlights of the Apollo Reliability and Quality Assurance Program during the 2nd Quarter 1965. Selected prior activities have been included where required to maintain information continuity. Section 2 is a summary based upon analyses of the Apollo-Saturn 201 Mission, the Apollo-Saturn Manned Lunar Landing Mission and the over-all Reliability and Quality Assurance Program. All references forming the basis for preparation of the report are contained in Appendix A. Each reference is identified by number where utilized in the text.

The second status report covering program activities during the 3rd Quarter 1965 will be issued in October 1965. Apollo-Saturn 201 Mission success, based upon latest available predictions, will be included together with an initial status summary of launch availability studies. Updated configuration and stage/module Reliability and Quality Assurance Program status will be presented for the Apollo-Saturn 201 Mission and initial status for the Apollo-Saturn 202 Mission. Mission success and crew safety, based upon predictions, will be presented for the first time for the Manned Lunar Landing Mission together with updated stage/module Reliability and Quality Assurance Program status. Apollo-Saturn Reliability and Quality Assurance Program management status will be expanded to include reliability and quality program resources.

SECTION 2: SUMMARY

2.1 GENERAL

The reliability and quality assurance status of the Apollo Program is presented with particular emphasis on the Apollo-Saturn 201 Mission and the first Manned Lunar Landing Mission. The information was obtained with the cooperation of the Reliability and Quality Assurance organizations at the MSF Centers. Insofar as possible, the many activities being conducted by these centers to assure success of the program are summarized to present an integrated picture of the Apollo Reliability and Quality Assurance Program.

The information in this summary is arranged as follows:

- Apollo-Saturn 201 Mission
- Apollo-Saturn Manned Lunar Landing Mission (Apollo-Saturn 504 Mission Configuration)
- Apollo Reliability and Quality Assurance Program

2.2 APOLLO-SATURN 201 MISSION

2.2.1 Overall Mission Reliability and Quality Highlights

- Test plans include verification of the differences between the Saturn I and Saturn IB.
- Completion dates for ground verification tests are slipping beyond Apollo-Saturn 201 Mission requirements with attendant increased mission risk.
- Component qualification tests of flight critical hardware are approximately 30% behind schedule.
- The majority of the reliability program requirements of NPC 500-5 are being implemented on Apollo-Saturn 201 Mission hardware.
- Single point failures have been identified.
- Current reliability apportionments correspond to an overall mission success goal of .84.
- Contractor Reliability predictions are being finalized.

2.2.2 Apollo-Saturn 201 Mission Status Approach. In determining the Apollo-Saturn 201 Mission status three approaches were used:

a. Evaluation of test plans for verification of the differences between the successful Saturn I program and the Saturn IB programs.

b. Evaluation of the Apollo-Saturn 201 R&QA Program status vs. plan.

c. Evaluation of the mission reliability through apportionments.

2.2.3 Verification of Differences Between Saturn I and Saturn IB. Analysis of the component qualification and ground tests scheduled indicates that appropriate plans have been made to evaluate all major differences between the Saturn I and Saturn IB before the Apollo-Saturn 201 Mission.

2.2.4 Component Qualification Tests. As of 1 June 1965, component qualification tests, Figure 2-1, that must be completed before flight, are 30% behind schedule. Problems such as CSM valve troubles and a need to redesign the helium pressure regulator may result in further slippage.

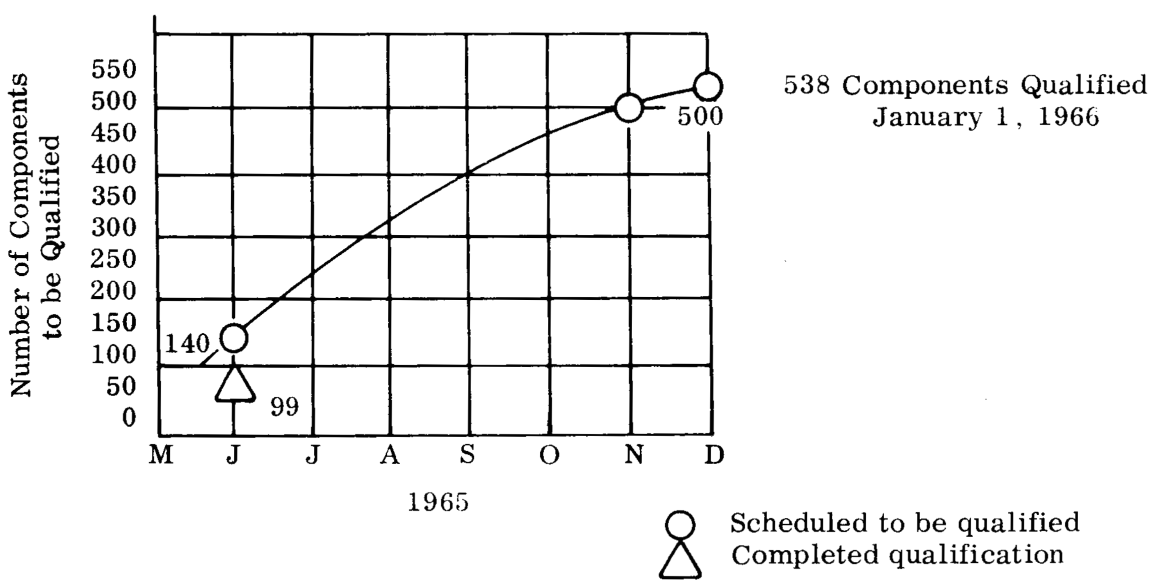


Figure 2-1. Apollo-Saturn 201 Mission Components Qualification Tests Scheduled vs. Completed

2.2.5 Ground Test Support. Major supporting launch vehicle and spacecraft ground tests for the Apollo-Saturn 201 Mission are scheduled for completion 15 December 1965. As of 1 June 1965 the following tests are behind schedule or are encountering problems which may cause schedule slippage.

S-IB Stage

- Spider beam structural failure during load tests
- Split tube on engine No. 7 after stage acceptance test firing
- Failure of sensor mounting brackets during qualification vibration

S-IVB Stage

- Predicted late delivery of flight stage to KSC checkout
- Weld failures in H_2 tank cylinder during structures test
- Schedule slippages on battleship program

IU

- Failure of mounting brackets during vibration
- Possible slippage in activation schedule of IU checkout station
- Schedule slippage of ESE causing late flight unit delivery

CSM

- Shortage of hardware for test slips SC007 test two months
- Slippage in SM 004 and CM 004A delivery
- Service Propulsion System and Reaction Control System problems delayed SC001 test one month

2.2.6 Mission Success Apportionment Status. Figure 2-2 presents a comparison of the relative contributions to unreliability of the five elements of the Apollo-Saturn 201 Mission based on apportioned values. The comparison indicates that, as might be expected for this short non-orbiting mission, the launch vehicle performance is considered to have the major effect on success. Apportionment analysis also indicates that the major predictable elements of risk are concerned with the operation of the S-IB and S-IVB.

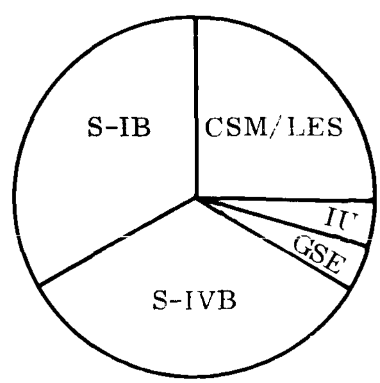


Figure 2-2. Apollo-Saturn 201 Mission % Contribution to Unreliability Based on Apportionments

Figure 2-3 presents a curve of probable reliability against mission phases based on the apportioned values. As shown, the apportioned reliabilities lead to a probability of mission success of 0.84.

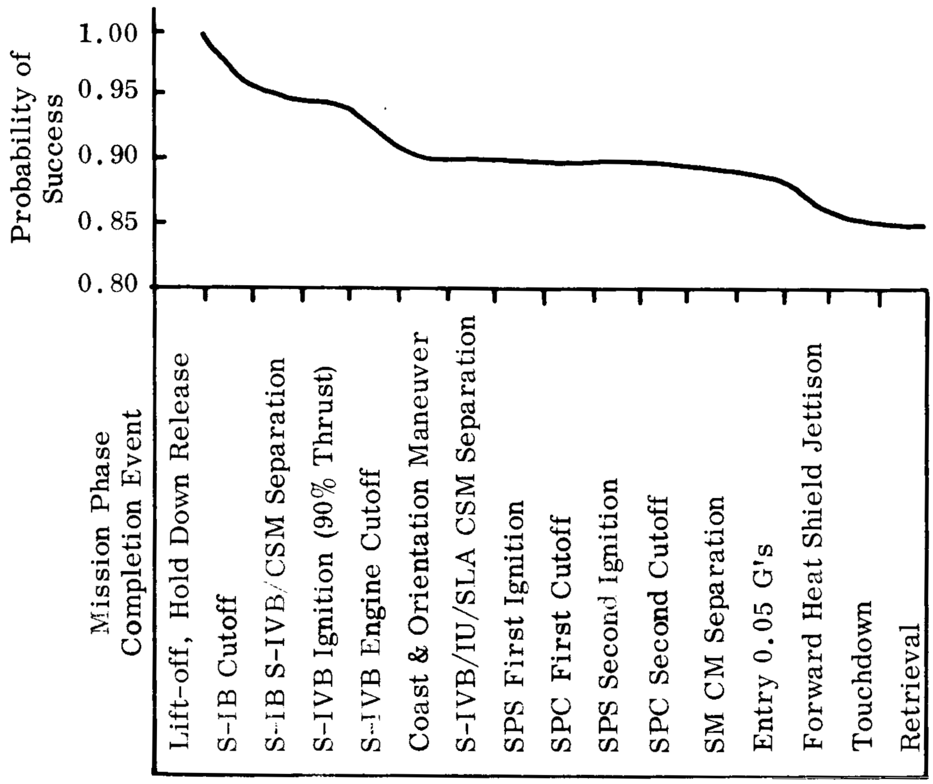


Figure 2-3. Apollo-Saturn 201 Mission Success Based on Apportionments

2.2.7 <u>Mission Success Prediction Status</u>. Since equipment reliability predictions for the Apollo-Saturn 201 Mission have not been finalized, a prediction of mission success is not included in this report.

2.2.8 <u>Reliability and Quality Program Implementation</u>. Implementation of reliability and quality assurance requirements of NPC 500-5 for the Apollo-Saturn 201 vehicle is progressing as shown in Figure 2-4. The relative degree of implementation for all major program phases is shown with the recognition that Apollo-Saturn 201 equipments are currently in the fabrication and ground test phases.

Areas of reliability and quality assurance implementation requiring program emphasis are:

- Improved failure and corrective action reporting, including equipment operating time records.

- Reliability and quality assurance training and the implementation of motivation programs at all levels.
- Audits at all program levels to promote appropriate reliability and quality assurance plan implementation.

Program Phase	S-IB	H-1 Engine	S-IVB	J-2 Engine	IU	CSM
<u>Conceptual</u>						
% Complete	68	68	68	32	68	68
% Initiated	32	0	32	68	32	32
% Unreported	0	32	0	0	0	0
<u>Design</u>						
% Complete	71	57	57	70	29	71
% Initiated	29	28	43	15	71	0
% Unreported	0	15	0	15	0	29
<u>Development</u>						
% Complete	100	68	68	68	32	32
% Initiated	0	0	32	32	68	68
% Unreported	0	32	0	0	0	0
<u>Fabrication</u>						
% Complete	40	40	40	20	20	20
% Initiated	40	40	40	60	60	80
% Unreported	20	20	20	20	20	0
<u>Ground Test</u>						
% Complete	30	43	0	15	0	0
% Initiated	45	42	45	85	60	40
% Unreported	25	15	55	0	40	60
GSE and GOSS - Unreported						

Figure 2-4. Apollo-Saturn 201 Vehicle Reliability and Quality Program Status

2.2.9 <u>Single Point Failure Analysis</u>. Single point failure analyses conducted by the contractors have identified the ten most critical items in each module. Failure of any one of these items would cause loss of stage or mission. Examination of Figure 2-5 indicates that half of these critical items are related to propulsion aspects of the mission and, that of these, half are related to valving. One quarter of the critical items are related to guidance and navigation and almost half of these concern gyros. The other quarter are related to electrical systems divided equally between power and switching elements.

	S-IB	S-IVB	IU	CSM (not ranked)
1.	Propellant Pumps and Gearbox Assembly - H-1 Engine	Selector Switch - Electrical Control	Gyros - ST-124M	Pitch Gyro- SCS
2.	Gas Turbine - H-1 Engine	Attitude Control Engine Assy. - APS	Battery D10- Primary Power	Yaw Gyro - SCS
3.	Fuel Additive Blender Unit - H-1 Engine	Electrical Distribution	Accelerometer ST-124M	Rate Gyros - CM/RCS
4.	LOX Replenishing Valve	Sequencer Mtg. Assy. - Electrical Control	Gas Bearing Regulator - Gas Bearing Supply	Helium Squib Valve - CM/ RCS
5.	Main Pump - H-1 Engine Hydraulic	Hydraulic Actuator	Battery D40- Primary Power	Propellant Isolation Valve - CM/RCS
6.	Separation and Retro EBW Trigger Relay - Main Distributor	Attitude Control Relay - Electrical Control	Servo Amplifier	Rocket Engine - CM/RCS
7.	High Pressure Accum-ulator - H-1 Engine Hydraulic	Actuation Control - Pneumatic Control	Memory "A" - LVDC	Helium Sole-noid - SPS
8.	LOX Fill and Drain Valve	Helium Regulation - Propellant Pressuri-zation	Memory "B" - LVDC	Helium Regu-lator - SPS
9.	Fuel Fill and Drain Valve	Hydraulic Pump	Slip Rings - ST-124M	Helium Check Valve - SPS
10.	Fire Separation and Retro Relay - Main Distributor	Power Distributor Mtg. Assy., 28VDC	Preamplifier and Detector - ST-124M	Rocket Engine Nozzle Exten-sion - CM/RCS

Similar information on GSE, ESE, and GOSS is not currently available.

Figure 2-5. Apollo-Saturn 201 Mission Critical Single Point Failure Analysis Results

2.3 APOLLO-SATURN MLL MISSION

2.3.1 Overall Apollo-Saturn MLL Mission Status. Analysis of the current reliability and quality program status of the first MLL mission indicates continual improvement of the individual efforts of the respective MSF Centers in conducting appropriate reliability and quality assurance activities. There is, however, indication that more emphasis should be applied to interfaces and consideration of the hardware and requirements in the total mission context. Inadequate emphasis is being applied to launch availability and the reliability aspects of logistics and maintainability.

Although program documentation is improving, there is an increasing need for an effective program-wide data and information exchange. The increased effectiveness of inter-center panels and the Apollo Document Index System constitute major improvements.

Current failure and corrective action reporting requirements are inadequate to provide information for program monitoring. This information provides a key measure of program progress toward scheduled goals by indicating the degree of convergence or divergence between equipment failure rate and failure correction rate.

Good progress has been made in the establishment of equipment reliability apportionments and predictions; however, specific detail profiles of the Apollo-Saturn 500 series missions have not been reported, hence current reliability apportionments and predictions are of a generic nature. Reliability mission profiles and system configuration utilized were based upon the Apollo-Saturn 504 Mission configuration, Apollo-Saturn 500 series missions program information, and the Design Reference Mission established by the Mission Planning Task Force at MSC. From this information a reliability mission profile has been assembled in sufficient detail to define functions which must be accomplished for mission success and crew safety. A need has been identified for program-wide dissemination of mission ground rules, operational procedures and guidelines for their application, to provide common objectives for all participants in the program.

2.3.2 Apollo-Saturn MLL Mission Reliability Apportionments. The Apollo Program Specification, NASA OMSF 005-001-1, establishes the goals for the Manned Lunar Landing Mission at 0.90 for mission success and 0.999 for crew safety. Figure 2-6 below summarizes the current stage/module apportionments made by the centers/contractors. Based upon these apportionments, probability of mission success is 0.73 and crew safety is 0.96.

Current center/contractor reliability apportionments for the S-IC and S-IVB stages are based on engine reliabilities of 0.999/engine. The stage reliabilities shown in the "Reconciled Contract Value" column are based on the engine reliability goals established in the engine contracts.

The values provided for Apollo-Saturn 500 series Design Reference Mission, mission success and crew safety (**) apportionments were computed using the "Reconciled Contract Value" reliabilities. Reliability apportionments for the Ground Operational Support System and for Ground Support Equipment have not been identified in program documentation.

**Calculated from above values

Stage/Module	Apollo Program Specification	Ref.	Contract Work Statement	Ref.	Program Plans	Ref.	Contractor Published	Ref.	Reconciled Contract Value
S-IC Stage	.95	1			.95	11	.95	104	.9071*
S-II Stage	.95	1			.95	11	.9155	82	.9155
S-IVB Stage	.95	1	.95	26	.95	11	.95	51	.9414*
Instrument Unit	.99	1			.992	11			.992
Command Service Module	.96	1			.9638	61	.9638	32	.9638
Lunar Excursion Module	.98	1	.984	35	.984	61	.987	97	.987
Overall Apollo-Saturn (Mission Success)	.90	1			.80**				.73**
Overall Apollo-Saturn (Crew Safety)	.999	1							.96**

* Contractual reliability goals for engines used in calculation for stage
** Calculated from above values

Figure 2-6. Apportionment Status, Mission Success Reliability Apollo-Saturn Manned Lunar Landing Mission

2.3.3 Reliability Program Implementation. Implementation of the requirements of NASA Document NPC 500-5 for the Conceptual, Design, and Development phases of the Manned Lunar Landing Mission is progressing as shown in Figure 2-7.

Program Phase	F-1	S-IC	S-II	S-IVB	IU	CSM	LEM
Conceptual							
% Complete	68	68	68	68	68	100	68
% Initiated	32	32	32	32	32	0	32
% Unreported	0	0	0	0	0	0	0
Design							
% Complete	43	29	57	57	0	42	29
% Initiated	57	71	29	43	71	29	57
% Unreported	0	0	14	0	29	29	14
Development							
% Complete	32	0	0	32	36	32	0
% Initiated	68	100	100	68	32	68	100
% Unreported	0	0	0	0	32	0	0
GSE and Goss unreported							

Figure 2-7. Reliability and Quality Program Status
Apollo-Saturn Manned Lunar Landing Mission

2.3.4 Single Point Failure Analysis. Active attention to single point failure analysis has been reported on all equipment areas except GSE, GOSS, and MCC. Most single point failure analyses of Apollo-Saturn 500 series mission hardware have not progressed to the point of identifying the most critical items, with the exception of those presented in Figure 2-8 below.

S-IC	S-IVB
1. Fuel Pressurization	1. Selector Switch
2. Fluid Power	2. Attitude Control Engines
3. Fuel Delivery	3. Helium Fill Modules
4. LOX Delivery	4. Electronics Assembly
5. Retro Rocket	5. Hydraulic Pump
6. LOX Pressurization	6. Auxiliary Propulsion Engine
7. Control Pressure	7. Electrical Distribution Cable
8. Engine Purge	8. Sequencer
	9. Separator

Figure 2-8. Most Critical Items Apollo-Saturn Manned Lunar Landing Mission

2.3.5 Manned Lunar Landing Testing and Reliability Prediction Status. Since the Apollo-Saturn 504 Mission is still in the design/development stage, testing has not progressed to the point permitting summarization of component qualification and ground test data. Preliminary reliability predictions have been made on most of the equipments and are currently being analyzed.

2.4 APOLLO RELIABILITY AND QUALITY ASSURANCE PROGRAM

The individual efforts of the respective MSF Centers in conducting reliability and quality assurance activities are effective, and the present plans for further coordination of these activities are directed toward more efficient utilization of the available resources.

2.4.1 Reliability and Quality Assurance Plans. Apollo R&QA plans are progressing toward maturity. The overall R&QA Program Plan is scheduled for approval August 1965. The MSFC R&QA Program Plan draft was issued 4 May 1965. MSC and KSC R&QA plans have been approved by center management and issued.

2.4.2 Single Point Failure Analysis Program. In response to the Associate Administrator's draft instruction on Single Point Failure Policy, areas of responsibility have been assigned to Apollo Program Office Directorates and an overall action plan is being prepared to identify those single failures which could have a significant impact on the program. Equipment reliability analyses being performed at all MSF Centers include analysis for failure effects and a criticality ranking of all components based on the failure impact. Coordination of procedures employed in these analyses is being undertaken since various criticality ranking methods are currently used.

2.4.3 Failure Reporting. Each of the Manned Space Flight Centers have initiated closed loop failure reporting systems. Further effort is needed to mature these failure reporting systems to permit adequate visibility by the centers and APO of critical/major failure and corrective action status.

2.4.4 Contractual Requirements. Some contracts between NASA and the prime contractors do not include adequate reliability and quality requirements.

2.4.5. Reliability and Quality Audits. Reliability and quality audits are scheduled and are being conducted by MSC and MSFC on major contractors. Implementing divisions at KSC are performing reliability and quality audits of facility and GSE contractors, but schedules are not available.

2.4.6 Mission Profiles. To assure common design and measurement goals, there is a strong need for the establishment of common mission profiles and ground rules for each mission and guidelines for their utilization by all participants in the program.

2.4.7 Reliability Modeling. The development of a compatible family of reliability analysis models at the program, center and contractor levels, has been initiated. Effort is presently directed toward establishment of guidelines and the implementation of technical interchange meetings to assure overall compatibility of the modeling efforts, particularly in interface areas. MSC has initiated an integrated modeling effort with its contractors. MSFC has modeling activities at all of its contractors.

2.4.8 Reliability Considerations of GOSS, Launch Complex Equipments and Crew Functions. At the mission level, current reliability analyses do not include meaningful reliability consideration of GOSS, launch complex equipments and crew functions.

2.4.9 Launch Availability. Studies have been initiated toward evaluation of launch availability. However, present plans indicate that summary results will not be available before mid-1966.

2.4.10 Crew Reliability Studies. Studies are being made by the Martin Company (OMSF Contract NASw-1187) to determine crew reliability; for example, (1) how well the crew performs switching functions and (2) how well the crew navigates and controls the spacecraft including fuel used.

2.4.11 Training and Motivation. Training courses are being utilized by the centers to better equip key center personnel to perform critical reliability and quality jobs. Motivation programs at each of the centers (for example, the Manned Awareness Program at MSFC) are being developed.

Seven contractors are reported to have initiated motivation programs such as Zero Defects or PRIDE.

Closer coordination of training and motivation programs has been initiated and will result in better utilization of available training resources.

SECTION 3: APOLLO-SATURN 201 MISSION

3.1 GENERAL

This section discusses the reliability and quality status of the Apollo-Saturn 201 Mission equipments. The information presented is intended to provide a basis for evaluating progress toward achieving desired mission reliability. The approach taken is one in which both quantitative and qualitative data have been considered to provide in-depth analysis of the probability of successfully performing the mission. This analysis follows three basic paths, Figure 3-1, each presenting a different visibility to program status.

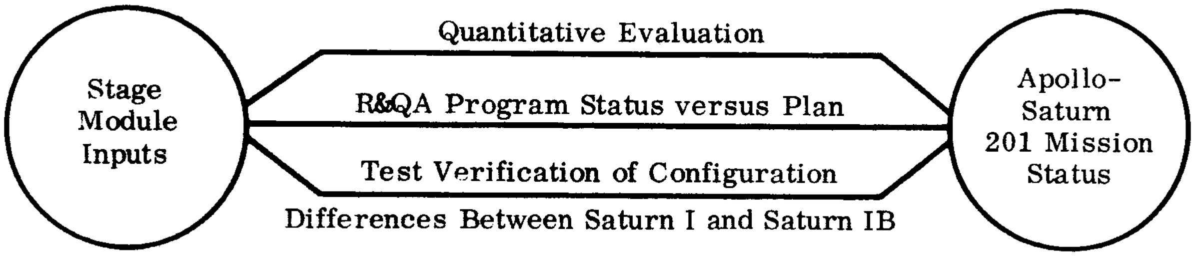


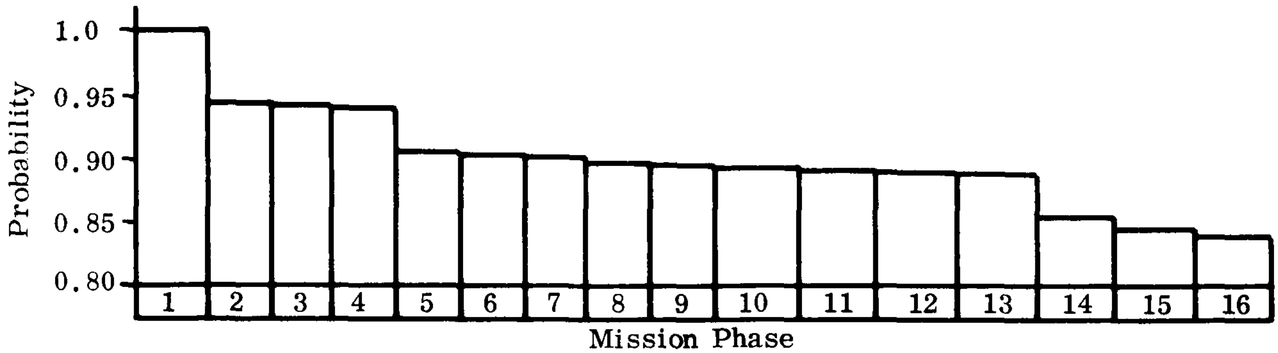
Figure 3-1. Apollo-Saturn 201 Mission Analysis Roadmap

The probability of the successful completion of the Apollo-Saturn 201 Mission based on reliability apportionments is estimated to be 0.84. The unconditional probability of completing each mission phase is shown on Figure 3-2.

The distribution of equipment unreliability contribution to the Apollo-Saturn 201 Mission is as follows:

S-IB-1 Stage	31%
S-IVB-201 Stage	31%
Spacecraft 009	26%
S-IU-201 Stage	6%
GSE	6%

These values are based on the reliability apportionments for the stages of the Apollo-Saturn 201 vehicle. A summary of the apportionments and predictions for each stage is tabulated in Figure 3-3.



Phase	Completion-Event	Phase	Completion-Event
1	Lift-off, Hold Down Release	9	SPS First Cutoff
2	S-IB Cutoff	10	SPS Second Ignition
3	S-IB - S-IVB/CSM Separation	11	SPS Second Cutoff
4	S-IVB Ignition (90% Thrust)	12	SM-CM Separation
5	S-IVB Engine Cutoff	13	Entry 0.05 G's
6	Coast & Orientation Maneuver	14	Forward Heat Shield Jettison
7	S-IVB/IU/SLA-CSM Separation	15	Touchdown
8	SPS First Ignition	16	Retrieval

Figure 3-2. Summary of Success Probabilities for Mission Phases

Stage	Apportionment	Ref.	Prediction	Ref.	Remarks
S-IB	.95	1	.957	44	
			.991*	47	*Based on no stage loss.
S-IVB	.95	1	.966*	52	
IU	.99	1	.9955*	57	
Spacecraft	.96	1	NOTE A	71	Prediction is due in September

Figure 3-3. Apollo-Saturn 201 Mission Apportionment and Prediction Status

NOTE A: No overall mission success probability based on prediction data is being presented in this report since the spacecraft contractor's prediction will not be available until September 1965. NAA/S&ID has reviewed the test program for the CSM subsystem and has estimated that successful completion of the planned testing will demonstrate 0.99 reliability for the CSM.

The overall summary of reliability and quality status on those items of flight hardware which have been designated for the Apollo-Saturn 201 Mission appears in Figure 3-4. The measurement yardstick used as a base is derived from the phased program elements of NPC 500-5, "Apollo Reliability and Quality Assurance Program Plan" (2).

NPC-500-5 Program Elements		Engines		Booster			CSM SLA
		H-1	J-2	S-IB	S-IVB	IU	
Reliability Goals	Conceptual Phase	C	C	C	C	C	C
R&QA Plan		U	I	I	I	I	C
Reliability Predictions		C	I	C	C	C	I
Apportionments	Design Phase	U	U	I	C	I	C
FMEA's		C	C	C	C	I	C
Specification Reliability Req.		C	C	C	C	I	C
Mission Profile		C	C	C	I	C	C
Human Eng. and Maint.		I	C	C	I	I	U
Parts and Materials		I	I	I	I	I	U
Test Requirements		C	C	C	C	C	C
Change Control	Development Phase	C	C	C	C	C	C
Critical Items		C	C	C	C	I	I
FR's and Corrective Action		U	I	C	I	I	I
Reliability Assessments	Fabrication Phase	I	I	U	U	U	I
MRB		C	I	C	C	I	I
Configuration Control		C	C	C	C	C	C
Program Reviews		U	U	I	I	I	I
Contractor Audits by Center		I	I	I	I	I	I
Qualification Tests	Ground Test Phase	C	I	I	I	I	I
Qual. Status List		U	I	C	U	I	I
Reliability Demo. Test		I	I	I	U	U	U
EI Accept. Tests		C	C	C	I	I	I
Checkout		C	I	I	I	I	U
Equipment Logs		I	I	U	U	U	U
Buy-Off		I	I	U	U	U	U

Key

C - Complete
I - Initiated
U - Status Unknown

Figure 3-4. Apollo-Saturn 201 Vehicle Reliability and Quality Program Status

A summation of single point failure analysis status for the stages of the Apollo-Saturn 201 flight vehicle is shown on Figure 3-5. All stage/module contractors have identified those items whose single failure could cause loss of the stage or degradation of the flight article.

Stage	Status of Critical Single Point Failure Analysis	Hardware Level of Critical Failure Identification	Total Critical Items	Ref.	Remarks
S-IB	Complete	Low Level Assemblies	92	45	Ranking by Criticality Number Method
S-IVB	Complete	Low Level Assemblies	92	52	Ranking by Criticality Number Method
S-IU	Preliminary	Low Level Assemblies	62	57	Ranking by Criticality Number Method
CSM and SLA	Preliminary	Low Level Assemblies	45	71	Ranked by high, low, unknown, and remote. No number or class assigned.
LES	Unknown				

Figure 3-5. Single Point Failure Analysis Status for Apollo-Saturn 201 Flight Vehicle

A summary of the qualification tests required prior to the Apollo-Saturn 201 flight is shown on Figure 3-6. Present status indicates that stage qualification test programs are behind schedule, particularly those in the spacecraft area.

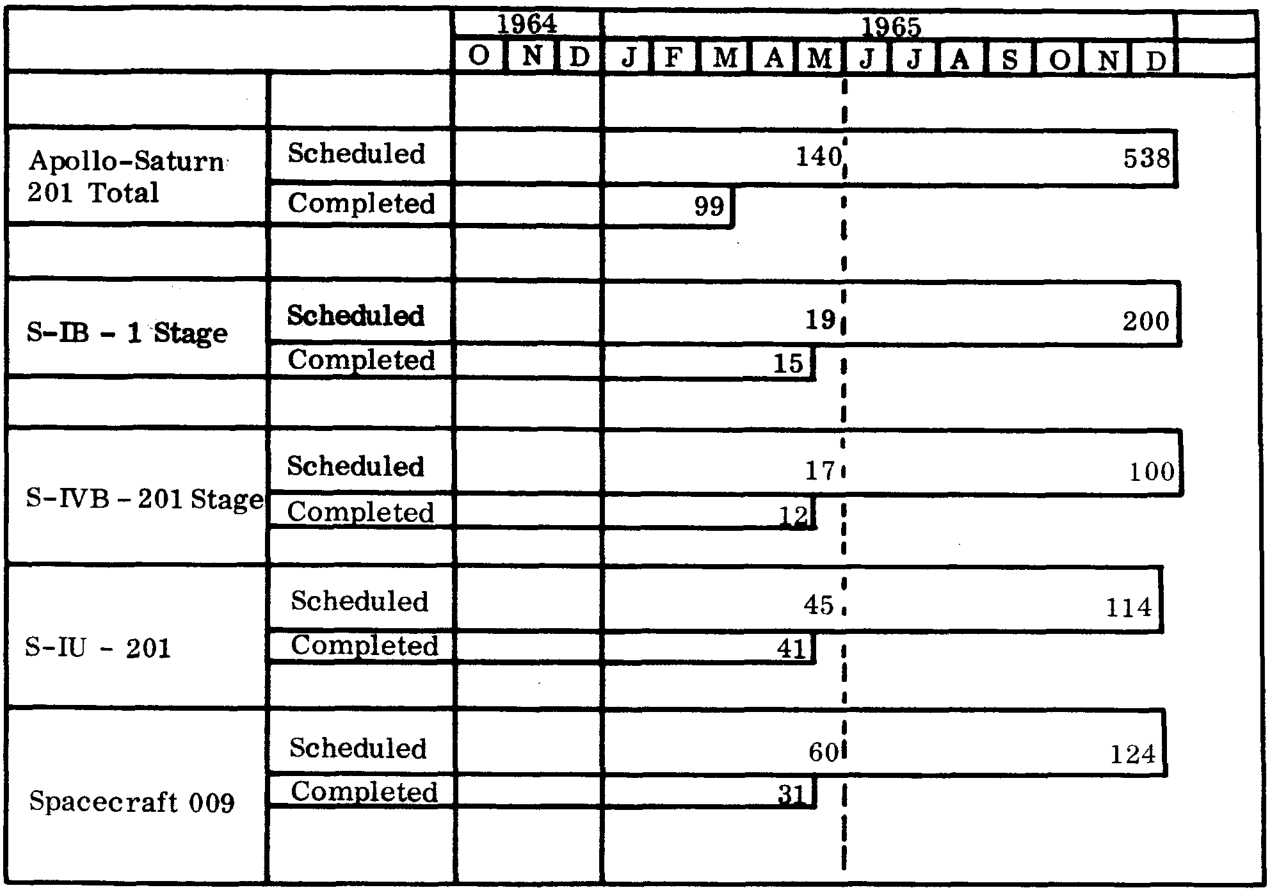


Figure 3-6. Apollo-Saturn 201 Mission Component Qualification Status

3.1.1 Accomplishments. Major reliability and quality assurance program accomplishments during this report period include:

a. Completion of FMEA's for S-IB-1 and S-IVB-201 stages.

b. An analysis of critical parts for each stage and module of Apollo-Saturn 201 flight article has been prepared (see summary on Figure 3-5).

c. Successful completion of the acceptance firing of the S-IB -1 stage on schedule 13 April 1965.

d. Completion of qualification of the H-1 engine 200K thrust configuration on 30 April 1965.

3.1.2 Problem Areas. Major reliability and quality assurance problems relating to the Apollo-Saturn 201 Mission include:

a. Completion dates for ground test constraints listed in the OMSF Mission Directive (8) are slipping because of equipment problems.

b. Qualification tests of flight critical hardware for the Apollo-Saturn 201 Mission are currently 30 percent behind schedule.

c. No forecasts of launch availability are being made for launch vehicle, spacecraft, or GSE.

d. The S-IU-201 is the pacing stage for the Apollo-Saturn 201 vehicle. Delivery is projected as late as October (versus a September required date) due to late delivery of ESE and activation problems of the IU checkout station at Huntsville. This may jeopardize planned IU stage checkout tests.

3.2 S-IB-1 STAGE

3.2.1 General

3.2.1.1 Configuration. The major differences between the S-1, Block II (19) and S-IB (17) stages are summarized as follows:

a. New lightweight Spider Beam.

b. H-1 engines upgraded from 188K to 200K lb. thrust each.

c. Redesigned separation system between S-IB and S-IVB stages.

d. Addition of ODOP transponder and antennae.

e. New fins and seal plate.

f. Increased measuring instrumentation.

g. Thinner wall LOX and fuel tanks.

3.2.1.2 Ground Test Constraints. S-IB-1 stage major-component structural testing required to support the Apollo-Saturn 201 Mission objectives is on schedule (4) and proceeding according to plan (see Figure 3-7) with one exception. The spider

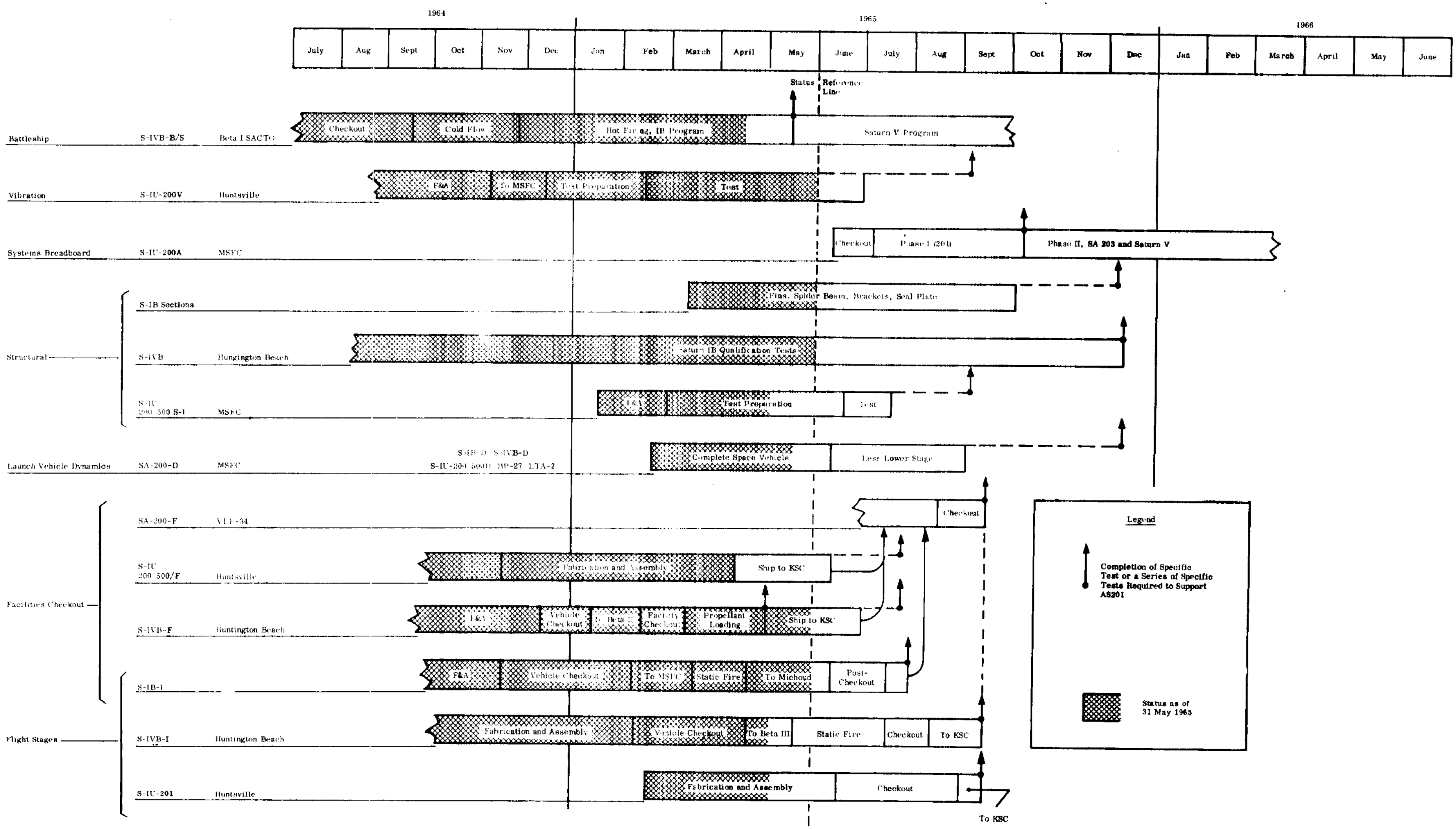


Figure 3-7. Saturn-IB Major Supporting Ground Tests for Apollo-Saturn 201 Mission

beam assembly failed during dynamic testing. The incorporation of fixes and the resumption of testing is planned to start June 7 with completion scheduled for mid-July.

The S-IB-1 stage completed acceptance firing tests on schedule 13 April 1965. During post-firing inspection, a split tube on Engine No. 7 was discovered. Plans call for the engine to be changed upon delivery of the stage to Michoud. An R&D engine was instrumented in support of a temperature profile test to determine if localized overheating might be the cause of tube failure. Preliminary analysis of data from six profile tests show no evidence of overheating.

The eight engines acceptance tested for the S-IB-1 stage were retrofitted to reflect the qualified H-1 configuration. This retrofit program included the installation of the following components (112).

a. Thrust chamber injector.

b. Thrust chamber LOX dome.

c. Main LOX valve - new bearings and shot peened shaft.

d. LOX boot strap line with fixed orifice.

e. Turbine No. 7 bearing.

f. Dual thrust OK pressure sensor.

Only start testing was utilized on the retrofitted engines to acceptance test the new hardware and minimize test time on the thrust chambers.

Figure 3-8 indicates the trend in quality performance of the Chrysler Corporation (CCSD) during S-IB manufacturing cycle. This is measured by determining the defects noted at the prime contractor's facilities per 1000 manufacturing man-hours (46).

Figure 3-9 shows the S-IB-1 stage component qualification (45) status by subsystems as of 1 May 1965. This chart does not include fifteen items under MSFC Astrionics responsibility.

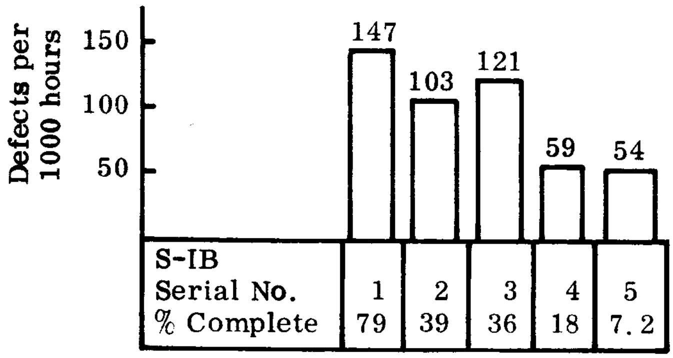


Figure 3-8. Defects Per 1000 Manufacturing Hours for April 1965

Two brackets, those supporting the LOX cut-off sensor and fuel cut-off sensor, failed during qualification test. Additional tests are being run by CCSD to determine if redesign is required.

Two H-1 engines, but not those scheduled for flight, have completed qualification testing in accordance with Rocketdyne contract requirements and Rocketdyne document R-6048, H-1 Engine 200,000 Pound Thrust Qualification Test Procedure. The Qualification Test Program was initiated 8 March 1965 and was completed 30 April 1965.

MSFC granted qualified status for the H-1, 200K engine on 3 May 1965 with the following Reliability assessment:

> Demonstration of 0.9946 with 50 percent confidence versus a demonstration goal (10) at completion of qualification testing of 0.99 at 50 percent confidence.

3.2.1.3 Critical Hardware. A single point failure analysis (FEA) (43) for all subsystems of the S-IB-1 stage was prepared by CCSD. Those items in this FEA whose single failure will result in a probability of vehicle loss are entered on the critical items list in descending order of criticality. The ten most critical items as a result of this analysis are shown on Figure 3-10.

3.2.1.4 Prediction and Estimations. The S-IB stage apportionment and prediction is shown on Figure 3-11. No data below the stage level was available for inclusion in this report. The prediction for the S-IB stage is based on 10,000 simulated flights (44) conducted by CCSD in April 1965.

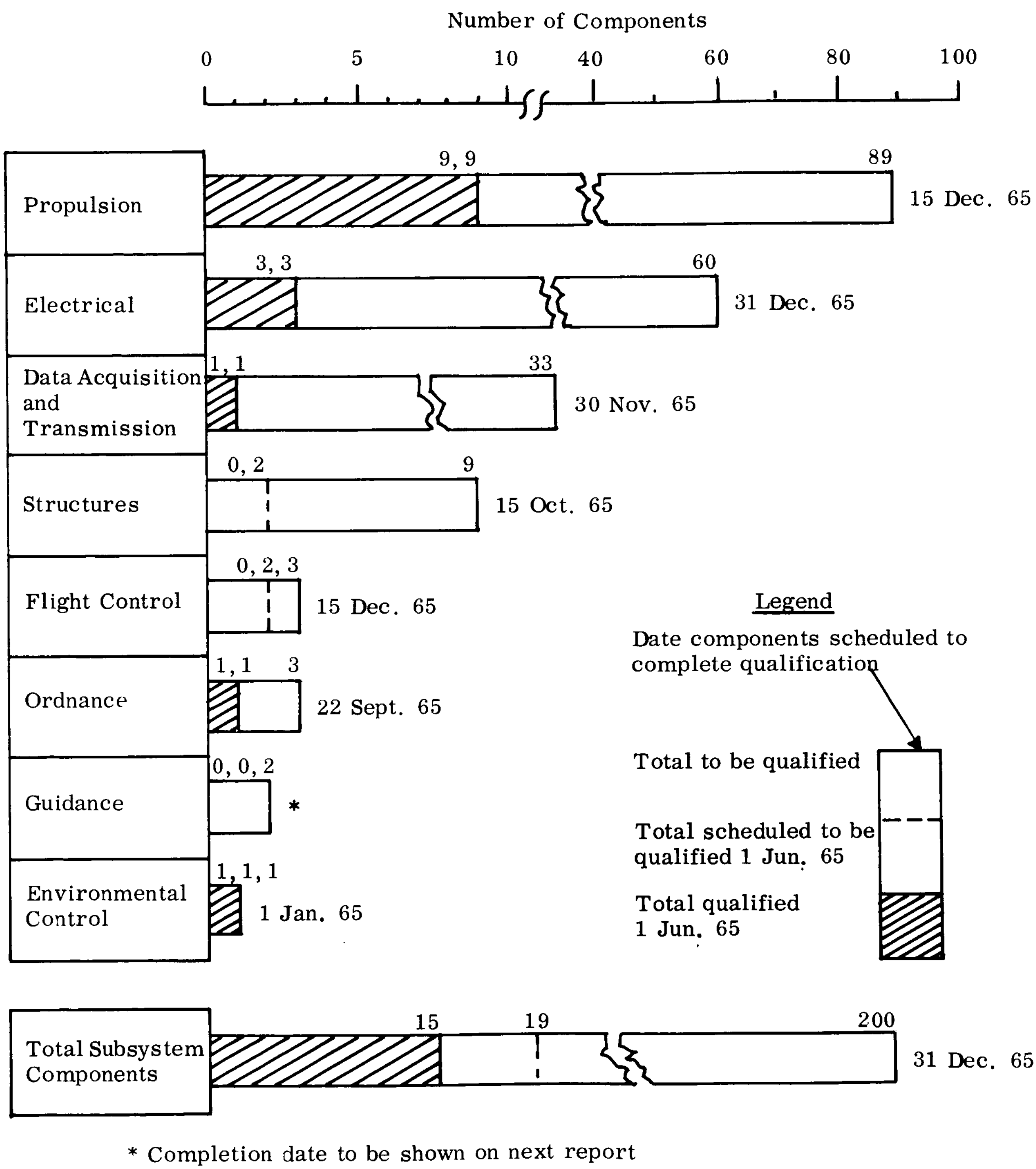


Figure 3-9. S-IB-1 Stage Component Qualification Status by Subsystem

Rank	Item	Subsystem
1	Propellant Pumps and Gearbox Assembly	H-1 Engine
2	Gas Turbine	H-1 Engine
3	Fuel Additive Blender Unit	H-1 Engine
4	LOX Replenishing Valve	LOX Replenish
5	Main Pump	H-1 Engine Hydraulic
6	Separation and Retro EBW Trigger Relay	Main Distributor
7	High Pressure Accumulator	H-1 Engine Hydraulic
8	LOX Fill and Drain Valve	LOX Fill and Drain
9	Fuel Fill and Drain Valve	Fuel Fill and Drain
10	Fire Separation and Retro Relay	Main Distributor

Figure 3-10. Ten Most Critical Items - S-IB-1 Stage

Stage	Apportionment	Ref.	Prediction	Ref.
S-IB	.950	1	.957	44

Figure 3-11. S-IB Apportionment and Prediction Status

3.2.2 Accomplishments

a. S-IB-1 acceptance firing tests completed on schedule 13 April 1965.

b. Chrysler Corporation Space Division completed Revision 1 to the Saturn S-IB-1 Stage System Design Analysis (43).

c. Qualification of the H-1 engine was completed on 30 April 1965 with reliability demonstration goals attained.

3.2.3 Problems

a. Cause of tube failure on H-1 engine during the acceptance firing test of S-IB-1 stage is undetermined.

b. Effectiveness of fixes on the spider beam assembly are not known.

3.3 S-IVB-201 STAGE

3.3.1 General

3.3.1.1 Configuration. The S-IVB stage is a new design evolved from a successful S-IV stage flown on Saturn I flights. The major differences between the S-IV (19) and S-IVB (17) stages are as follows:

a. Major structural redesign.

b. New propulsion system with 200,000 lbs. thrust single J-2 engine versus the 90,000 lbs. cluster of six RL-10A-3 engines on S-IV stage.

c. Reduced number of ullage rockets used.

d. Increased instrumentation measurements and telemetry equipment.

e. Increased tankage volume.

f. Auxiliary propulsion system added for roll and stabilization control.

3.3.1.2 Ground Test Constraints. The OMSF flight directive (8) has specified the test constraints, Figure 3-7, required of the S-IVB-201 configuration hardware. The following paragraphs present the status of these major ground tests:

The S-IVB-201 flight stage was installed on Beta III test stand on 7 May 1965. Static firing tests were initiated 24 May 1965.

S-IVB structure test is scheduled for completion in mid-December 1965. The hydrostatic test was terminated in July 1964 due to fracture of a longitudinal weld in the hydrogen tank cylinder. The failure resulted in changes to welding techniques which are presumed to be satisfactory. It was considered (54) by MSFC that sufficient tank test data was obtained to validate the design.

Installation of the J-2 engine into the S-IVB battleship structure is presently in process. First firing of J-2 engine, No. 2020, is scheduled for 17 June 1965.

Both Flight Readiness Test (FRT) J-2 engines have completed hot fire acceptance testing. Initiation of FRT is presently scheduled for 9 June 1965.

A summary of the S-IVB Component Qualification Program is shown on Figure 3-13.

3.3.1.3 Critical Hardware. A failure effects analysis (FEA) was conducted by Douglas in March 1965 in which the single-failure contribution to stage loss was identified for the S-IVB-201 stage (51). Subsequently, a critical items list was generated using the MSFC criticality ranking technique for these single-failure items. The ten most critical items are shown on Figure 3-12.

Rank	Item	Subsystem
1	Selector, Switch	Electrical Control
2	Engine Assembly	Auxiliary Propulsion
3	Electrical Distribution	Electric Distribution
4	Sequencer Mounting Assembly	Electrical Control
5	Actuator Assembly, Hydraulic	Hydraulic
6	Attitude Control Relay	Electrical Control
7	Module, Actuation Control	Pneumatic Control
8	Module, Low Pressure Helium	Propellant Pressurization
9	Auxiliary Hydraulic Pump Assembly	Hydraulic Power Supply
10	Power Distribution Mounting Assembly, Aft, 28 VDC	Electrical Control

Figure 3-12. Ten Most Critical Items - S-IVB-201 Stage

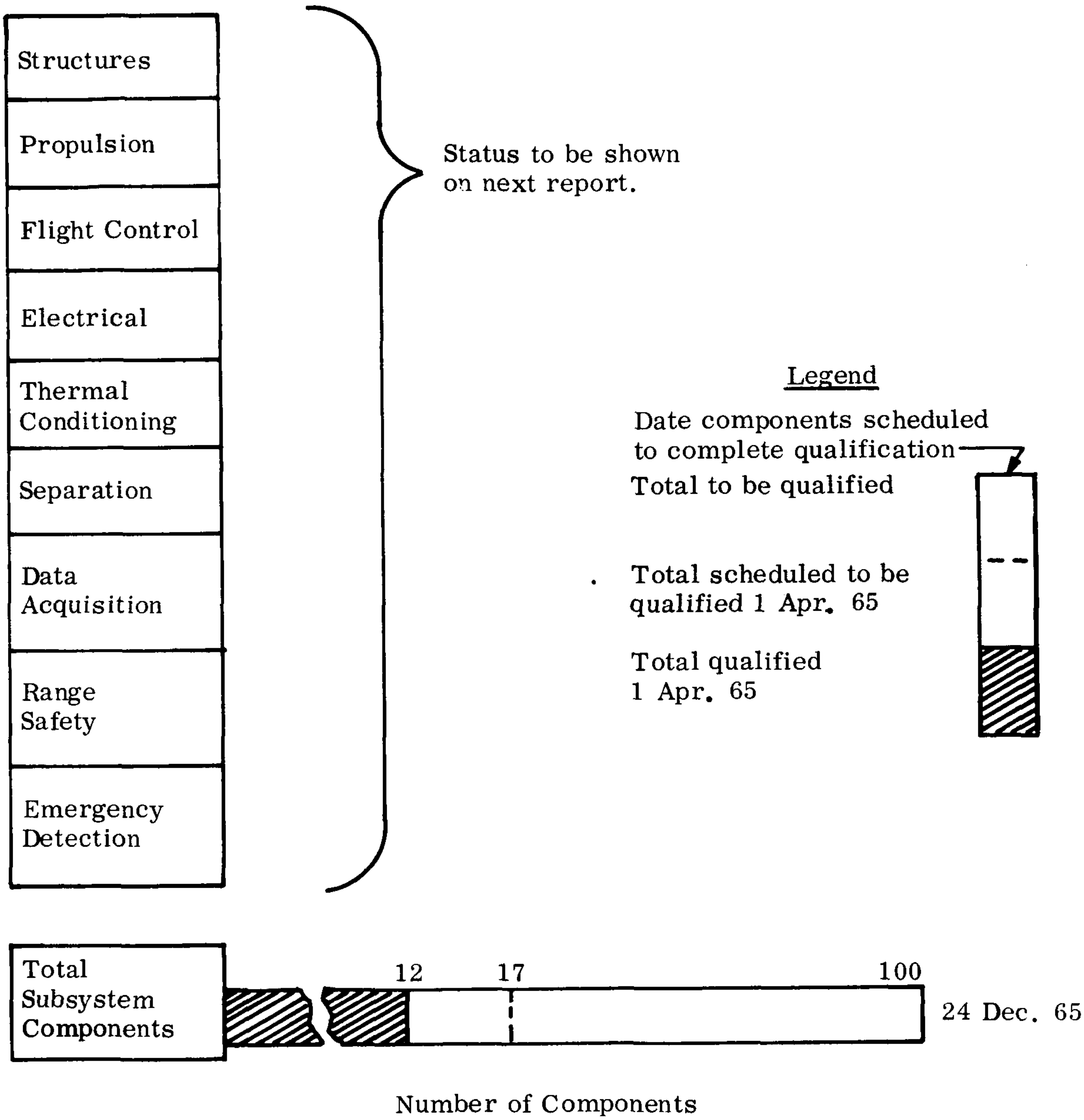


Figure 3-13. S-IVB-201 Stage Component Qualification Status by Subsystem

[redacted]

3.3.1.4 Predictions and Estimations. The apportionment and prediction status of the S-IB/S-IVB program is shown on Figure 3-14. Douglas is predicting a mission success probability of 0.9660 for the S-IVB-201 stage against an apportionment of 0.950.

Stage or Subsystem	Apportioned	Ref.	Predicted	Ref.	Assessed	Ref.	Remarks
S-IVB Stage	.950	1	.9660	52	-	-	-
Structure	.999890	52	.999890	52	-	-	-
Propulsion	.9780	52	.9850	52	-	-	-
Flight Control (Hydraulic)	.999967	52	.99720	52	-	-	-
Flight Control (Aux. Prop.)	.999720	52	.99410	52	-	-	-
Electrical	.999840	52	.990010	52	-	-	-
Thermal Conditioning	.999998	52	.999998	52	-	-	-
Separation (from S-IB)	.9720	52	.999770	52	-	-	-

Figure 3-14. S-IVB Apportionment and Prediction Status

3.3.2 Accomplishments. The following significant accomplishments have occurred during the reporting period:

a. The S-IVB-201 flight stage completed vehicle checkout and has been installed in Beta III test stand. Hot firing was begun on 24 May 1965.

b. Hot fire acceptance of the two J-2 engines for FRT has been completed.

3.3.3 Problems. S-IVB-201 problems can all be related to the tight schedule to meet the earliest possible launch date. Any new problems could throw the program behind schedule preventing an early launch.

[redacted]

3.4 S-IU-201 STAGE

3.4.1 General

3.4.1.1 Configuration. The major differences between the IU stage used on the Saturn I, Block II vehicles and the Apollo-Saturn 201 vehicle are summarized below:

a. New structure - larger and different type construction.

b. Updated guidance and control system.

c. Revised electrical power system.

d. Emergency Detection System.

3.4.1.2 Ground Test Constraints. Status of the supporting ground tests being conducted to satisfy the OMSF flight directive is as follows:

Mounting brackets for four components failed during Y-axis testing on the S-IU-200V unit earlier this year. The failures were identified as inadequate bonding of brackets to structure. An additional program to qualify mechanically fastened brackets began on 27 May and is to be completed 30 June.

A wire corrosion problem in the ST-124M Stabilized Platform is being corrected with nickel plated wire. This change will be effective with the S-IU-203 Unit. The original type wire will remain in the S-IU-201 and 202 units. The program, Figure 3-7, for the Flight Unit is indicated as being on schedule for a mid-September required delivery at KSC. Late delivery of ESE and activation problems of the IU checkout station at Huntsville, however, will delay checkout of the Flight Unit, and expected delivery is the end of October.

Because of this late availability, three systems will be retro-fitted and checked out during later program phases as follows:

Launch Vehicle Data Adapter (LVDA) and Launch Vehicle Digital Computer (LVDC) will be phased in during manufacturing checkout in August.

Flight Control Computer to be delivered to KSC in October for installation during the Pre-launch Activities.

The delivery delay for the first two systems was due to solderability problems and fracturing of the ULD S-Clip.

Corrective action was instituted in manufacturing welding processes and techniques. Continued monitoring is warranted to ascertain at the earliest possible date the acceptability of these changes.

A summary of qualification status by subsystem is presented in Figure 3-16. Significantly, the structures components scheduled for completion of testing by 1 July 1965, have not started qualification (55).

3.4.1.3 Critical Hardware. A preliminary Failure Mode, Failure Effect, and Criticality Analysis for the S-IU-201 Instrument Unit was issued by IBM on 23 May 1965 (57). Criticality determinations were accomplished for those components capable of causing vehicle or mission loss. A summary of the ten most critical items appears in Figure 3-15.

Rank	Item	Subsystem
1	Gyros	ST-124M
2	Battery D10	Primary Power
3	Accelerometer	ST-124M
4	Gas Bearing Supply Regulator	Gas Bearing Supply
5	Battery D40	Primary Power
6	Servo Amplifier	Platform Electrical Assembly
7	Memory "A"	Launch Vehicle Digital Computer
8	Memory "B"	Launch Vehicle Digital Computer
9	Slip Rings	ST-124M
10	Preamp and Detector	ST-124M

Figure 3-15. Ten Most Critical Items - S-IU-201

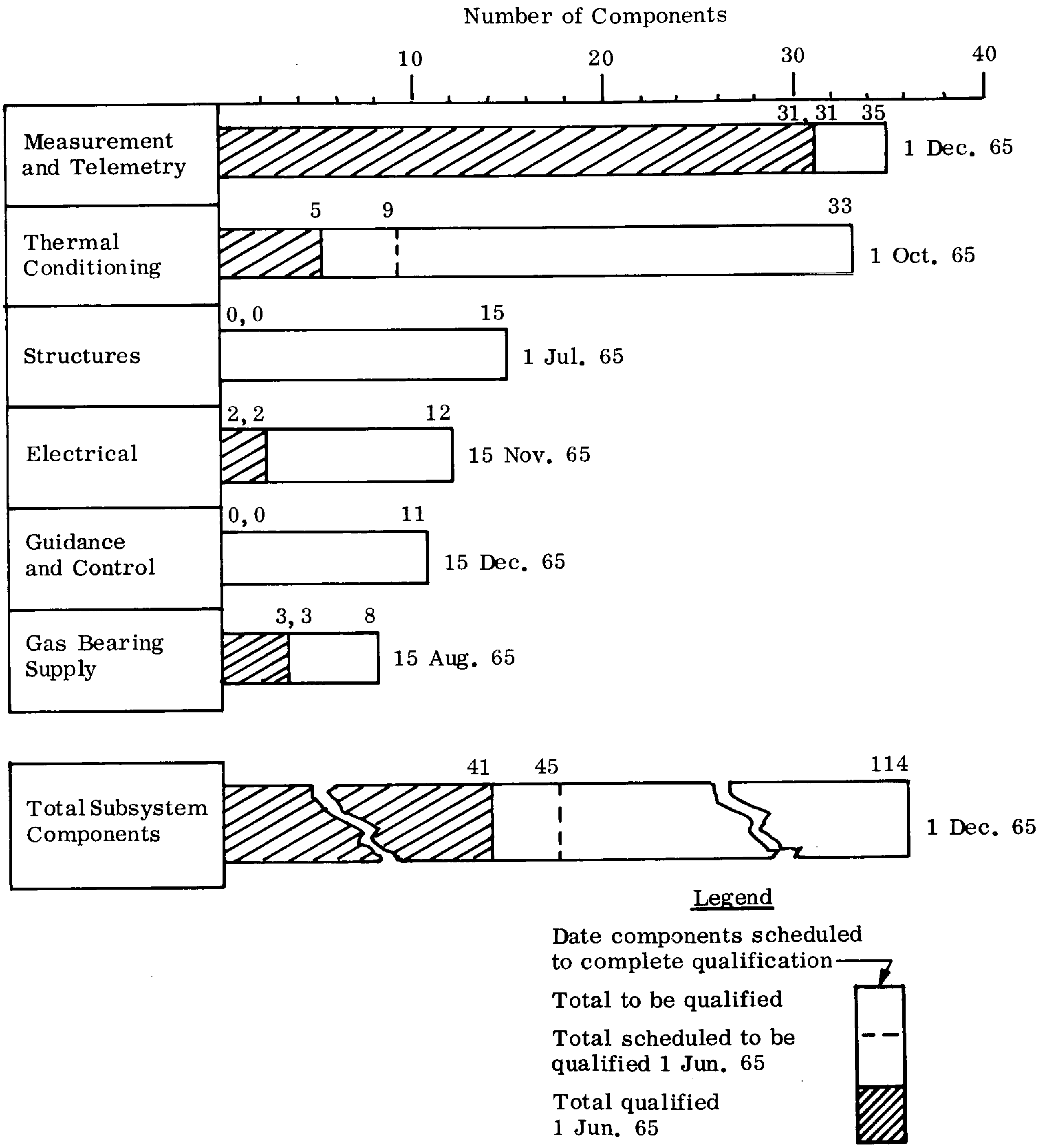


Figure 3-16. S-IU-201 Component Qualification Status By Subsystem

3.4.1.4 Predictions and Estimations. Figure 3-17 shows a summary of reliability apportionments and predictions for the S-IU-201.

Stage or Subsystem	Apportioned	Ref.	Predicted	Ref.	Assessed	Ref.	Remarks
Stage-Instrument Unit	.990	1	.9955	57	-	-	-
Structural	No data available		1.0	57	-	-	-
Thermal Conditioning			1.0	57	-	-	-
Emergency Detection			1.0	57	-	-	-
Instrumentation and Communications			1.0	57	-	-	-
Guidance and Control			.9967	57	-	-	-
Electrical			.9988	57	-	-	-
Tracking			1.0	57	-	-	-

Figure 3-17. S-IU Apportionment and Prediction Status

3.4.2 Accomplishments

a. Publication of preliminary IBM Failure Mode, Failure Effect, and Criticality Analysis for S-IU-201 on 23 May 1965 - final report to be issued before 23 August 1965.

3.4.3 Problems

a. Structure components qualification test slippage should be evaluated (see paragraph 3.2.3.3) against meeting the earliest launch date.

b. Further evaluation of mounting bracket requalification should be made against earliest launch date feasibility.

3.5 SPACECRAFT 009

3.5.1 General

3.5.1.1 Configuration. Spacecraft 009 will be the first flight-configuration spacecraft to be flown on the Apollo Program. Saturn I flights were made using boilerplate versions and dummy hardware.

The Spacecraft 009 will consist of the command module (CM), the service module (SM), spacecraft-LEM adapter (SLA), and the complete launch escape system (LES).

The CSM will generally be of manned flight configuration less the following equipment:

a. Guidance and navigation system

b. Fuel cells

c. Waste management system

d. Water supply systems

e. Crew provisions

The necessary control function to accomplish a non-orbital, high heat rate mission, will be performed by the Automated Control Subsystem (ACS), comprised of the altitude reference system and the control programmer system.

The Launch Escape System (LES) that will be used on SC 009 is essentially the same as that used in the Little Joe II and Saturn I development programs. The launch escape and pitch control motors have been qualified, and qualification tests have been completed on the tower jettison motor. The elements of the LES that still require qualification include the boost protective cover, canards, and tower separation explosive bolts. The remaining scheduled Little Joe II and Saturn I flights should accomplish this and no problems are anticipated.

3.5.1.2 Ground Test Constraints. The presently defined critical ground test program supporting Spacecraft 009 (31), Figure 3-18, consists of a series of comprehensive tests of specific command module, service module, and SLA hardware. The following summarizes the status of each test activity.

SC004 - The major test status problem that could affect reliability involves Spacecraft 004, the static structural test vehicle. There is a one month delivery slippage of SM004, and a two month delivery slippage of CM004A (4). This combination of schedule slippage and accelerated Apollo-Saturn 201 launch date could result in a reliability compromise. Failure to satisfactorily complete the CSM004 static structural tests prior to the flight of

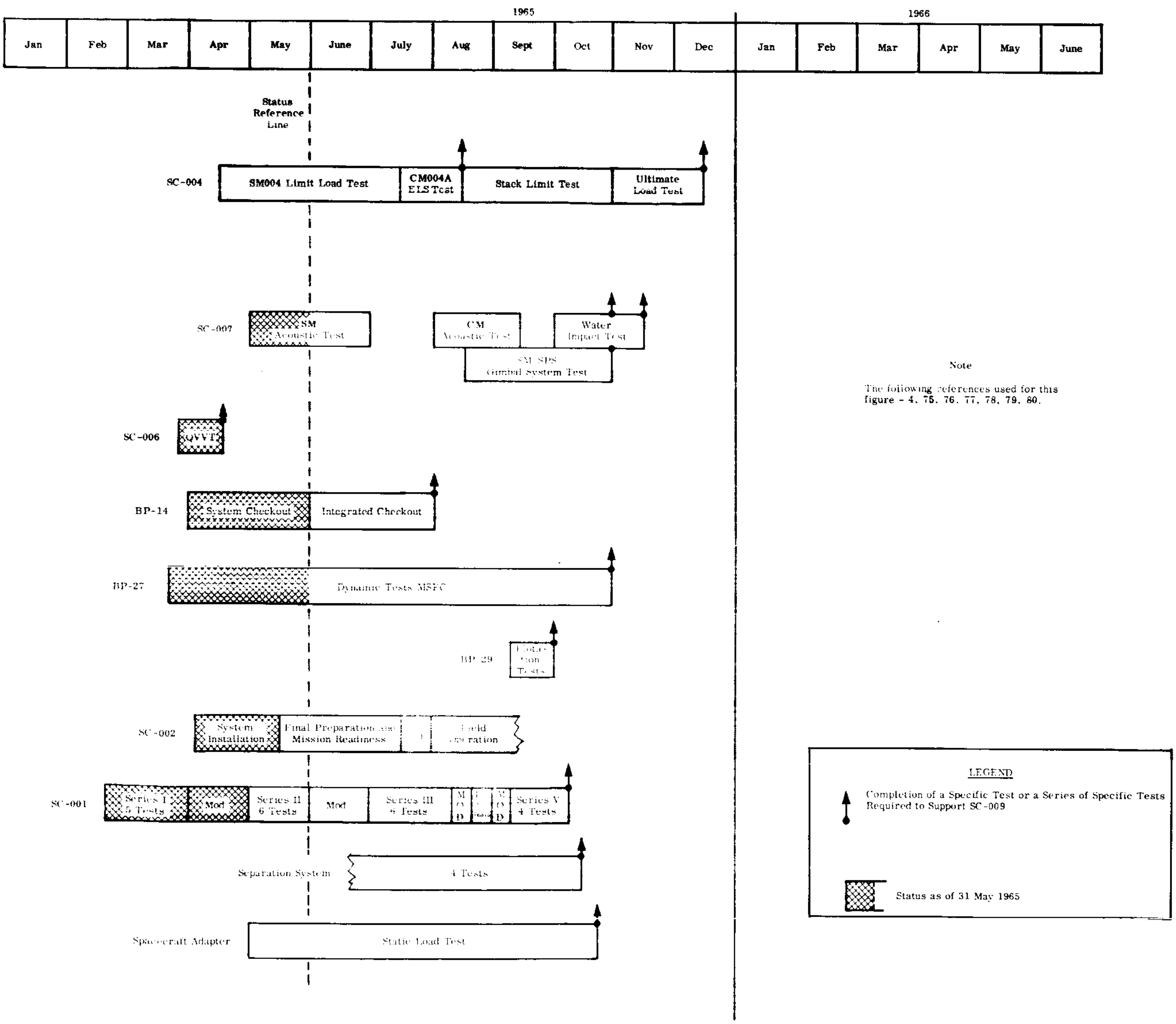


Figure 3-18. Spacecraft 009 Supporting Ground Tests for Apollo-Saturn 201 Mission

Spacecraft 009 would represent a real loss of confidence in the structural integrity of the command, service module.

SC007 - This test has been rescheduled based on a two month slippage in the fabrication cycle. Present scheduled completion date is shown as 15 November 1965, however the MSF schedules (4) indicate a potential slippage as late as March 1966.

SC006 - The Qualification Vibration Verification Test was completed in April 1965. No further testing is planned on this vehicle for Spacecraft 009.

BP14 - All tests are on schedule and proceeding satisfactorily.

BP27 - All dynamic tests are on schedule and proceeding satisfactorily.

BP29 - Installation of the modification kit for the uprighting subsystem is scheduled to begin July 19. Qualification sea tests are planned to start 15 September 1965. The purpose of this test is:

a. Verify spacecraft structure flotation and stability.

b. Evaluate uprighting subsystem.

c. Evaluate post landing electronics.

d. Evaluate mechanical location aids.

SC002 - Installation of equipment into the Spacecraft 002 airframe is approximately one month behind schedule. The flight test for Spacecraft 002 will be for structural verification of CM/LES airframe during a 25,000 foot abort. The test also evaluates the design of the CM-SM umbilical and umbilical cutter.

SC001 - The Series I thru Series V test will demonstrate reliable equipment operation of the SPS and satisfy the constraints listed in the mission directive. The Series I tests, which are complete, have satisfied the following objectives: normal operation, transient, helium subsystem, and single valve bank. Modifications for Series II tests are now complete. Start of this test sequence is approximately one month behind schedule, however no slippage in completion date for the Spacecraft 001 test is forecast. There are no provisions to test fire a Service Module Reaction Control System and Service Propulsion System concurrently. This will result in the loss of the following test program objectives (75):

a. Evaluate the reactions of combined system operations upon each other.

b. Determine the capability of the RCS to perform a roll maneuver during an SPS firing with gimbal actuation.

c. Evaluate system operational characteristics of SPS and RCS using battery power.

d. Mission support of Spacecraft 009 to determine if onboard battery systems will supply the required power output for proper systems operation.

These tests were originally scheduled to be conducted on Spacecraft 001. However, a hardware shortage of reaction control systems necessitated removal of the RCS from Spacecraft 001 for utilization with the spacecraft facility verification vehicle at KSC. This will afford KSC the opportunity of developing and improving their handling and checkout procedures involving the RCS.

QUAL - The component qualification test status is presented in Figure 3-19. Only the components of the specific subsystems required to support the the flight of Spacecraft 009 (31) are shown. The eight subsystems have a total of 124 components that must complete qualification testing prior to the launch of Apollo-Saturn 201. As of 1 April 1965, 31 out of a scheduled 60 components had completed qualification. This represents considerable slippage in the component qualification program.

Three subsystems have component qualification tests that could become problem areas if the present schedule slippage is not resolved. These

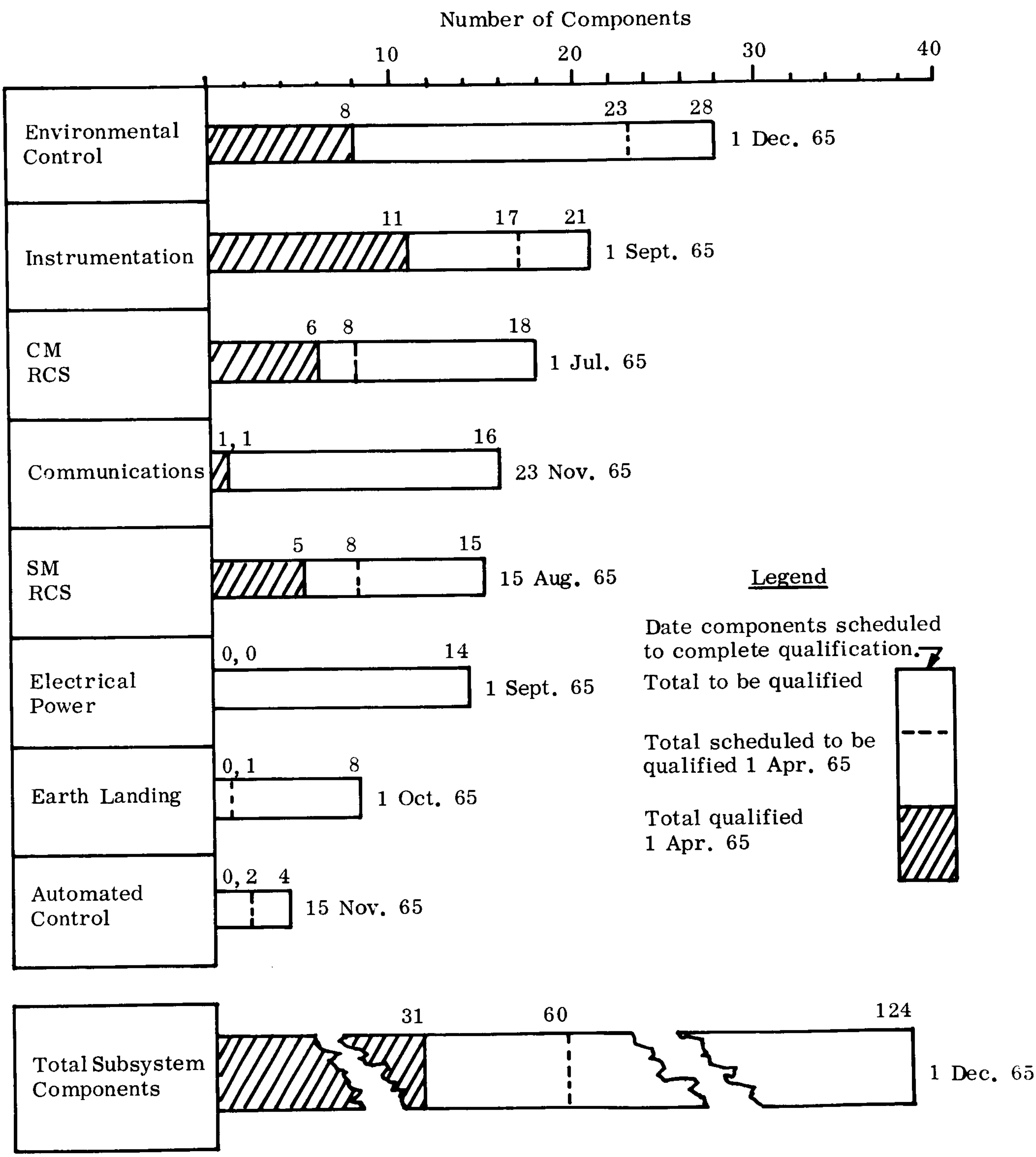


Figure 3-19. Spacecraft 009 Component Qualification Status by Subsystem

subsystems and their respective components are: (74)

	Scheduled Test Dates	
	Start	Completion
a. Environmental Control System		
• Cold Plates, Eutectic Bonded	3/19/65 to	12/1/65
• Space Radiator Structure	5/1/65 to	12/1/65
b. Automated Control System		
• Control Programmer	6/1/65 to	11/15/65
c. Communications System		
• VHF/FM Transmitter Equipment	8/12/65 to	11/23/65
• VHF/AM Transmitter and VHF Recovery Beacon	8/12/65 to	11/23/65
• Audio Center Equipment	8/12/65 to	11/23/65
• VHF Multiplexer	8/31/65 to	11/23/65

3.5.1.3 Critical Hardware. A preliminary single point failure analysis was conducted by NAA/S&ID for Spacecraft 009 on 12 April 1965, in which the failure mode, probable cause, and failure effect on the mission was defined. No attempt was made to rank or to assign relative numerical values to these single failures. Figure 3-20 summarizes the ten items identified as having "high" probability of failure and whose failure could cause loss of mission objectives.

3.5.1.4 Predictions and Estimations. NAA/S&ID is in the process of developing a functional assessment mathematical model for Spacecraft 009. The present plan calls for completion of this effort on 10 September 1965.

3.5.2 Accomplishments

a. MSC reported that Thiokol completed qualification tests on the tower jettison motor.

b. MSC reported that the qualification test program has been completed on the launch escape and pitch control motors and that these motors have been accepted by NASA.

c. MSC reported that the Apollo standard initiator has completed qualification testing.

Rank	Item	Subsystem
N/A	Attitude Gyro-Pitch	Stabilization and Control
N/A	Attitude Gyro-Yaw	Stabilization and Control
N/A	Rate Gyros (Pitch and Yaw)	Stabilization and Control
N/A	Rocket Engine Nozzle Extension	Reaction Control (CM)
N/A	Helium Squib Valve	Reaction Control (CM)
N/A	Propellant Isolation Valves	Reaction Control (CM)
N/A	Rocket Engine	Reaction Control (CM)
N/A	Helium Solenoid	Service Propulsion
N/A	Helium Regulator	Service Propulsion
N/A	Helium Check Valve	Service Propulsion

N/A - Not Available

Figure 3-20. Ten Most Critical Items - Spacecraft 009

3.5.3 Problems

a. Design review approval has been withheld for the Command Module Reaction Control System pending resolution of the tank rupture-landing impact problem. Effect on the Apollo-Saturn 201 vehicle is undetermined as yet.

b. Repeated failures at low temperature of the reefing line cutters in the Earth Landing System have caused the subcontractor to investigate an alternate source of supply.

c. A new pneumatic valve actuation system is in the development process to resolve the erratic opening and closing times for the bipropellant ball valves on the Service Propulsion System.

d. Completion of the ground tests on Spacecrafts 004 and 007 are behind schedule. Tests must either be replanned or Spacecraft 009 may be launched with some ground tests incomplete.

e. Some problems have been experienced in the development and qualification program of a dual mode explosive bolt for LES tower separation. If the requirements are not met, it may be necessary to use the single mode explosive bolt.

f. The adhesive bonding techniques and controls used on the CM structures of earlier vehicles are in question. Failure occurred during the bonding integrity test on Spacecraft 002. Bonding failures also occurred on Spacecraft 006 and Spacecraft 009. This condition could have serious effects on the present schedule for the flight of Apollo-Saturn 201 unless timely resolution can be made.

3.6 LAUNCH COMPLEX 34 AND GSE

3.6.1 General

3.6.1.1 Configuration. Launch Complex 34 was last used for launching the Saturn I, Block I vehicles. Modifications and additions to Launch Complex 34 facilities were necessary, therefore, in order to accommodate the Apollo-Saturn-IB vehicles and to provide systems for manned spacecraft operations. Detailed descriptions of these modifications are found in the Launch Complex 34 Modification Plan (38); major work items identified in this plan arc:

a. Addition of High Pressure Gaseous Hydrogen System

b. Addition of Emergency Ingress/Egress System

c. Modifications to Propellant Systems

d. Addition of Apollo Access Arm and Accessories

e. Modifications to Swing Arms and Accessories

f. Provision for Hazardous Gasses and Vapors (MMH, N_2O_4, UDMH)

g. Modifications to Environmental Control System

Launch operations GSE for the launch vehicle and spacecraft includes equipment for (1) handling spacecraft during mating with launch vehicle, (2) installing pyrotechnic devices, (3) final fluid and gaseous systems servicing, and (4) verification of vehicle readiness. Launch complex operations for the

Spacecraft and the required supporting GSE are identified and described in the Ground Operations Requirements Plan (73).

3.6.1.2 Launch Complex/GSE Checkout. In addition to qualification of each individual system, an integrated test of all launch operations systems is planned to demonstrate the compatibility of Launch Complex/GSE/Space Vehicle. This over-all Launch Complex checkout, planned to begin in August, is a major element of the over-all testing program designed to establish mission success capability. In addition to reducing mission risk through verification of equipment, it will serve to verify launch operations procedures and exercise safety systems under simulated launch conditions. Information will also be obtained on spares and preventive maintenance programs. The plan for this checkout (37) has recently been issued but was not available for consideration in this status report. Utilization of the "live" S-IB-1 stage in this checkout (4) will require careful review to assure no degradation of flight systems is incurred.

3.6.1.3 Reliability Analyses. Reliability analyses, including Failure Effect Analysis, Criticality Number Determination, and Alternate Mode of Operation Analysis, are planned for Launch Complex GSE and Instrumentation equipment as reported in Section III of the KSC Apollo R&QA Plan (36). The results of some preliminary FEA work based on the Saturn I Configuration were presented to the Crew Safety Panel in April, 1965 (40). Ninety-nine items had been identified as Priority I (capable of causing vehicle loss) at that time. Systems which include one or more of these items are:

- Valve Panel No. 10 (LOX Dome Purge)
- Umbilical Swing Arm No. 1
- Umbilical Swing Arm No. 2
- Umbilical Swing Arm No. 3
- Valve Panel No. 5
- RP-1 System
- Holddown Arms
- Short Cable Masts
- GN_2 Facility
- Valve Panel No. 9

- Combustion Stability Monitor (Safety Item)
- Fire Detection Monitor (Safety Item)

Spacecraft GSE analysis is being performed by MSC contractors. In order to organize analysis efforts, NAA/S&ID has grouped GSE as (68):

ME I = Mission Essential, Criticality I

ME II = Mission Essential, Criticality II

MS = Mission Support, Criticality III

The ME I items are those in which undetected failures could jeopardize crew safety or create a personnel hazard and ME II items are those in which failures could cause launch delays or, if undetected, could cause mission abort. Mission Support items are not critical from a safety, launch delay, or abort standpoint. Reliability analyses have been performed primarily on Mission Essential items. Spacecraft 009, to be used on the Apollo-Saturn 201 Mission, requires approximately fifty items of GSE in this category.

The NAA analysis efforts have included preparation of logic block diagrams, single-point failure effect analysis, design reviews, and function utilization diagrams at submodule levels. Reliability estimates have been made on many items. In addition, House Spacecraft I (BP 14) is being used to simulate and support the mission assigned to Spacecraft 009, and GSE experience is being obtained from that program. NASA/MSC has approved the NAA/S&ID GSE Qualification test program and electromagnetic compatibility program (70).

An assessment of Spacecraft 009 GSE is presently in process and is scheduled for completion on 15 August 1965. Test data from all previous launches and test sites, including House Spacecraft I, will be incorporated in the analyses (70).

The ACE-S/C equipment being manufactured by General Electric constitutes another major part of Spacecraft GSE. Failure Mode Effects and Criticality Analyses are being made. The composite FMEA's will be completed during the third quarter of 1965, dependent upon timely receipt of GFE inputs. System reliability predictions completed in March 1965 and subsequent assessment of operational stations indicate the equipment meets the reliability goals (87).

The status of FEA work being done by MSFC contractors is known only for Electrical Support Equipment (ESE). FEA's are completed for I. U. ESE and are 75 percent complete for S-IVB ESE Power System, Auxiliary Power Systems, and the S-IB ESE Power System (88).

3.6.1.4 Predictions and Estimations. No consideration of launch complex or GSE reliability has been included in the Mission Reliability Analysis presented in Section 3.7. That is, the numerical probability estimate of successful operation has been assumed to be 1.0.

3.6.2 <u>Significant Accomplishments</u>

a. The Launch Complex 34 Checkout Plan was completed and issued by KSC.

b. The NAA/S&ID plan of action for the GSE qualification test program (CCA 117) was approved, and qualification test specifications are being prepared.

3.6.3 <u>Problem Summary</u>. No over-all forecasts of launch availability have been made at this time.

3.7 MISSION RELIABILITY ANALYSIS

3.7.1 <u>General</u>. This section presents a summary of the probabilities of mission success for the Apollo-Saturn 201 Mission based on models and computations made from contractor apportionments. Center and contractor sources provide data on the individual stages or subsystems.

Contractors are in the final stages of making predictions. Contractor predictions are available on the launch vehicle; however, the NAA/S&ID prediction on the spacecraft will not be available until September. The resulting lack of data in finalized form prevents the formulation of a mission success estimate based on contractor and center predictions at this time.

3.7.2 <u>Mission Success Goals</u>. Apportionments for the Apollo-Saturn 201 Mission, at the subsystem level, were compiled from many sources. These are shown in Figure 3-23.

A summary of the computations of mission success is presented in Figure 3-21, using the normalized profile of Figure 3-22 and the data of Figure 3-23. Each unconditional number listed represents the probability of the mission reaching the beginning of the given subphase, i.e., the probability of successfully completing the sequence of events required before the particular subphase can be started. Each conditional number listed represents the probability of completing the particular subphase, provided the previous events have occurred successfully so that the subphase has been started. The assumption is made that all systems are "go" at the end of the countdown or at hold down release. Thus the unconditional system reliability is 1.0 at liftoff.

EVENTS	SUBPHASE NUMBER	Computed Mission Success Based on Apportionment	
		TO BEGINNING OF PERIOD (Unconditional)	DURING SUB-PHASE (Conditional)
Start Countdown			
	1	(not modeled, assumed to be 1.0)	
Lift-Off, Hold Down Release			
	2	1.0	.941793
S-IB Cutoff			
	3	.941793	.999979
S-IB S-IVB/CSM Separation			
	4	.941774	.999890
S-IVB Engine Ignition (90% thrust)			
	5	.941671	.960420
S-IVB Engine Cutoff			
	6	.904400	.996069
Coast and Orientation Maneuver			
	7	.900845	.999682
S-IVB/IU/SLA CSM Separation			
	8	.900559	.997011
SPS First Ignition			
	9	.897868	.995804
SPS First Cutoff			
	10	.894101	.999888
SPS Second Ignition			
	11	.894001	.999767
SPS Second Cutoff			
	12	.893793	.999758
SM CM Separation			
	13	.893577	.999139
Entry, 0.05 G's			
	14	.892808	.954170
Forward Heat Shield Jettison			
	15	.851891	.988539
Touchdown			
	16	.842128	.998792
Retrieval			
Over-all (At end of retrieval)		.841111	---

Figure 3-21. Apollo-Saturn 201 Mission Success by Phases Based on Apportionments

ELAPSED TIME IN SECONDS		EVENTS (subphase extends from ---- to)	NORMALIZED PROFILE		
MSFC PROFILE (14 & 15)	MSC PROFILE (31)		ELAPSED TIME IN SECONDS	SUBPHASE NUMBER	SUBPHASE TIME IN SECONDS
		Start Countdown			
				1	---
0.0	0.0	Liftoff, Hold Down Release	0.0		
				2	146.3
146.3	144.3	S-IB Cutoff	146.3		
				3	0.8
147.1	145.1	S-IB S-IVB/CSM Separation	147.1		
				4	4.8
151.9	149.9	S-IVB Engine Ignition (90% Thrust)	151.9		
				5	454.9
606.8	615.8	S-IVB Engine Cutoff	606.8		
				6	249.0
	855.8	Coast and Orientation Maneuver	855.8		
				7	20.0
	875.8	S-IVB/IU/SLA CSM Separation	875.8		
				8	390.2
	1266.0	SPS First Ignition	1266.0		
				9	180.0
	1446.0	SPS First Cutoff	1446.0		
				10	15.0
	1461.0	SPS Second Ignition	1461.0		
				11	10.0
	1471.0	SPS Second Cutoff	1471.0		
				12	31.5
	1502.5	SM CM Separation	1502.5		
				13	112.5
	1615.0	Entry, 0.05 G's	1615.0		
				14	425.0
	2040.0	Forward Heat Shield Jettison	2040.0		
				15	441.0
	2481.0	Touchdown	2481.0		
				16	(48 hrs. max.)
	----	Retrieval	(48.68 hrs. max.)		

Figure 3-22. Apollo-Saturn 201 Mission Profile

SYSTEM OR SUBSYSTEM	APPOR-TIONED	REF.
S-IB Stage (over-all)	.950000	1
S-IVB Stage (over-all)	.950000	52
Structure	.999890	52
Propulsion	.978000	52
Flight Control (Hydraulic)	.999967	52
Flight Control (Aux. Prop.)	.999720	52
Electrical	.999840	52
Thermal Conditioning	.999998	52
Separation	.972000	52
Data Acquisition	.993800	51
Instrument Unit (over-all)	.990000	1
Malfunction Detection System (Emergency Detection System)	.999700	23
CSM (over-all)	.960000	1
CSM Structure	.999945	61
Electrical Power	.998600	61
Instrumentation	.999990	61
SLA Structure	(1.0)	
Separation (from SM)	(1.0)	
LES (over-all)	.999949	65
Separation	.999990	65
Pitch Control Motor	.999000	65
Jettison Motor	.999950	68
Launch Escape Motor	.998000	68
Tower Structure	.999990	65
Canard	(1.0)	
SM (over-all)	.995730	61
Propulsion (SPS)	.999400	61
Reaction Control System	.999400	61
Jettison Controller	.999000	63
PAM/FM/FM Transmitter	(1.0)	

SYSTEM OR SUBSYSTEM	APPOR-TIONED	REF.
CM		
Environmental Control	.990000	61
Earth Landing System	.999940	61
Reaction Control System	.999950	61
Stabilization and Control	.995000	63
Control Programmer	.992000	63
Master Events Sequencer Control	.999000	63
Attitude Reference	.996200	63
Radio Command Control	.995200	67
VHF/FM Transmitter	.999960	68
Premodulation Processor	.996700	68
HF Transceiver	.999720	68
VHF Recovery Beacon	.999810	68
Signal Conditioner	.988000	68
Data Storage Equipment	.993000	68
C-Band Transponder	.999500	68
PCM Telemetry	.963000	68
VHF Multiplexer	(1.0)	
PAM/FM/FM Transmitter	(1.0)	
Flight Qual. Recorder	(1.0)	
GFE Survival Beacon	(1.0)	
Heat Shield Integrity	(1.0)	
Separation System (SM-CM)	(1.0)	
Radio Command Receiver	(1.0)	
Impact and Flotation	(1.0)	
Eastern Test Range	(1.0)	

Figure 3-23. Contractor Inputs for Mission Success

3.7.3 Mission Profile. For modeling purposes as presented in this report, the Apollo-Saturn 201 Mission has been divided into subphases as shown in Figure 3-22. Particular events which can be monitored during the flight and which are compatible with the available contractor information were chosen from the many events in the detailed profiles (Reference 31 and 15) for the Apollo-Saturn 201 Mission. The profile obtained from Marshall Space Flight Center is utilized to the beginning of phase 6, and the Manned Spacecraft Center profile is used for the rest of the mission. A minor difference in event times between the two missions is reconciled during phase 6.

3.7.4 Mission Analysis Approach. Stage (or top level) models are too coarse for adequate description of mission events and for obtaining estimates for the probabilities of meeting mission objectives. Subsystem (or second level) models are used because they provide a readily understandable representation of the functional events required during the actual flight. If no goal is available, an estimate of 1.0 is used for computational purposes. Only mission success is considered in this report, since there is no crew and hence no crew safety requirements for the Apollo-Saturn 201 Mission. A typical block diagram of an apportionment model, that used for mission subphase 2, lift-off through S-IB cutoff, is shown in Figure 3-24. Most subsystems appear as series elements in the models, indicating that they are mission essential.

Studies are underway to evaluate the effects of trajectory variations which may occur during the flight. Similarly, studies of two abort modes, one using the Launch Escape System during the early flight period, and the other using the Service Propulsion System after LES jettison, have been started.

3.7.5 Ground Support. Ground Operational Support System (GOSS) coverage for the Apollo-Saturn 201 Mission will be provided by the Eastern Test Range (ETR) of the National Range Division.

Figure 3-25 shows the planned ground plot derived from the Apollo-Saturn 201 Mission profile. The bars indicate the approximate range of coverage from each of the specific ETR sites (and ships). It can be seen that most of the functional events occuring during the flight are monitored by the planned network.

Further analysis of the reliability related to the ETR network is expected to be made when the descriptions of the specifics of the ground systems support, "SA-201 Mission Support Requirements" and "Apollo SA-201 Mission Operations Plan", become available.

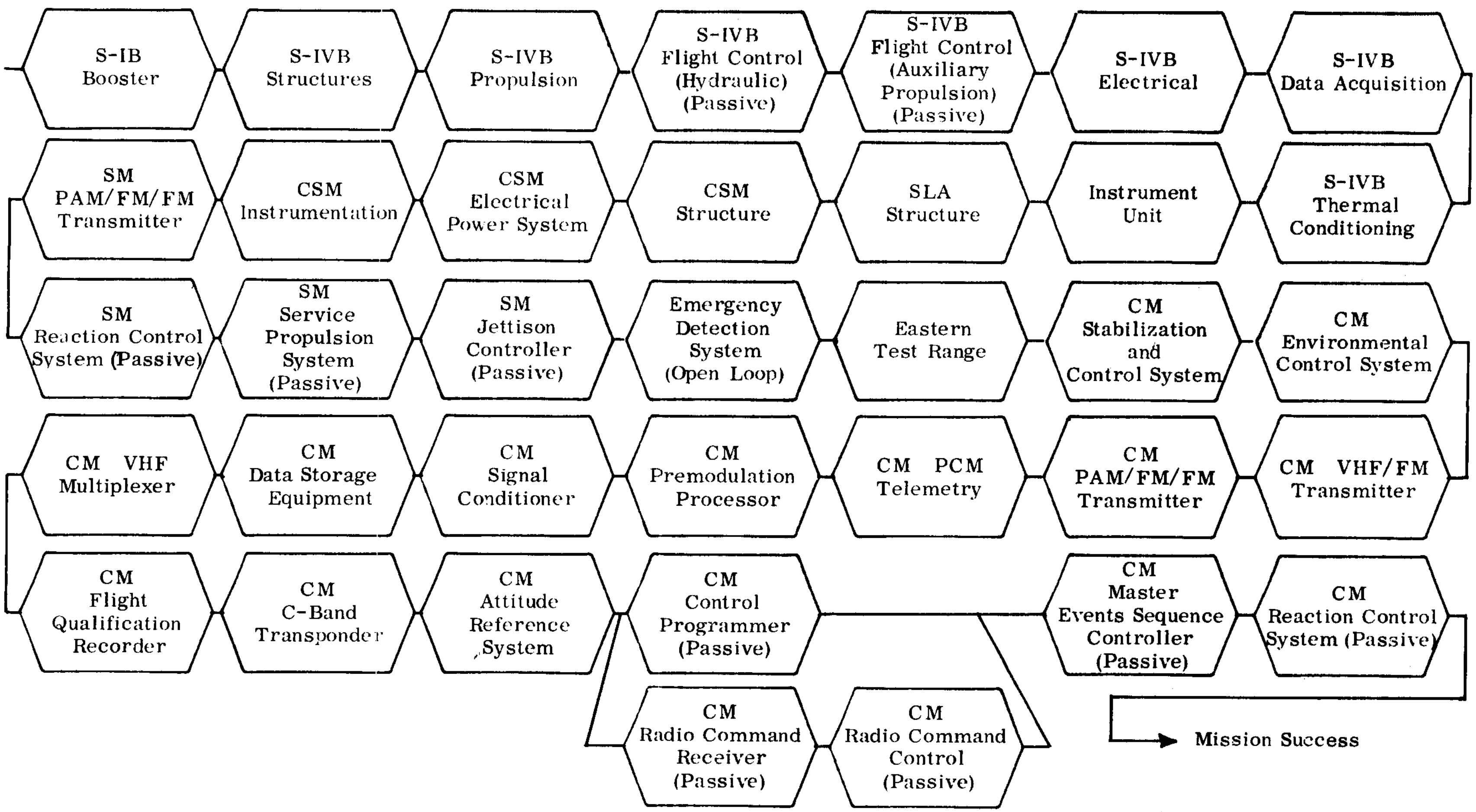


Figure 3-24. Mission Success Apportionment Model Subphase 2

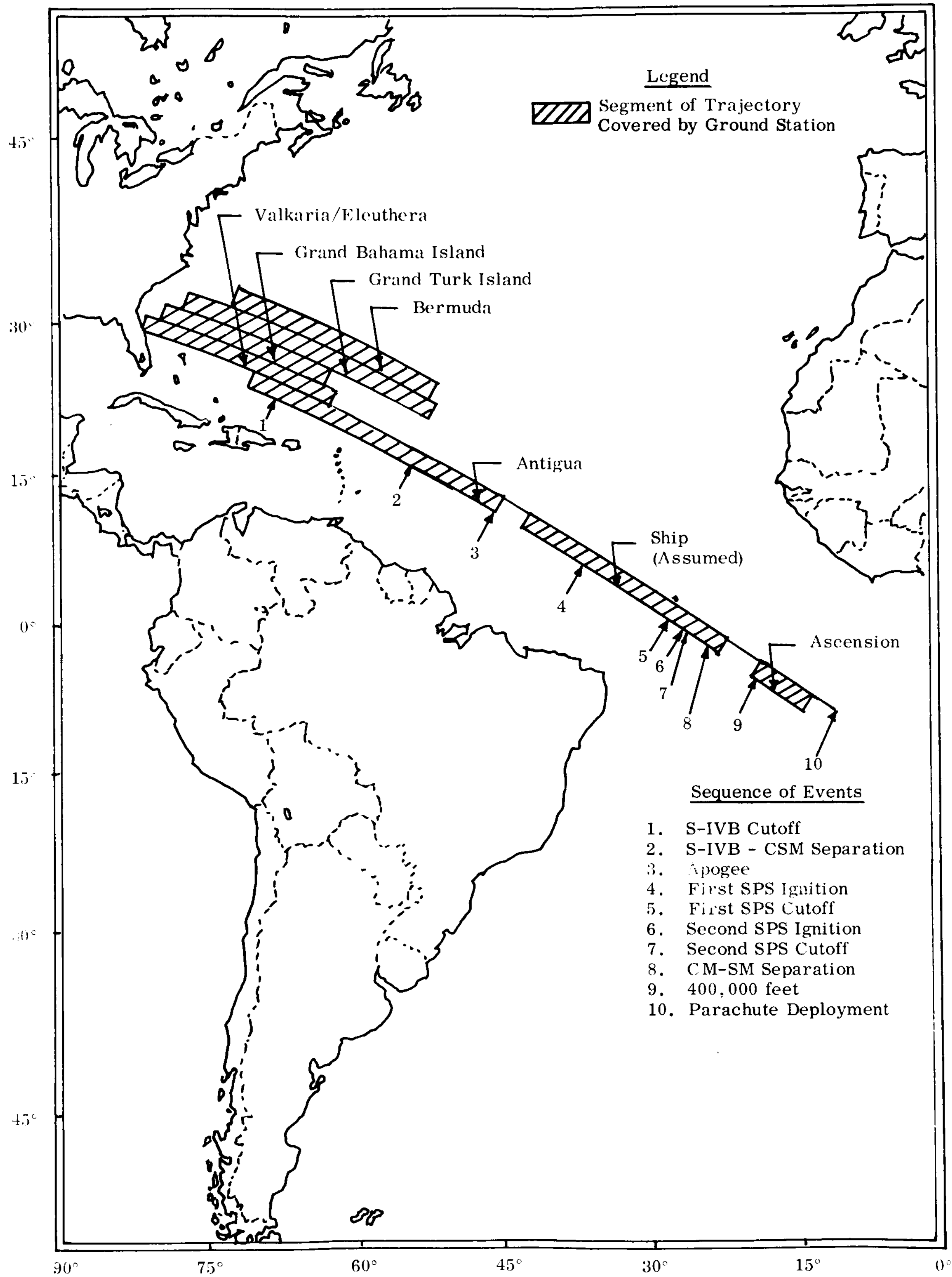


Figure 3-25. Eastern Test Range Support for 201 Mission

SECTION 4: APOLLO-SATURN (MLL) MISSION

This section discusses the status of the Apollo-Saturn Manned Lunar Landing (MLL) Mission Reliability and Quality Assurance Program. The Mission Analysis discussion herein has been specifically related to the Apollo-Saturn 504 Mission. Stage and module status, however, has been described in terms of the Apollo-Saturn 500 series equipments. This approach has been necessary because (1) portions of the hardware required for the Apollo-Saturn 504 Mission have not as yet been designated, (2) the availabile reliability information does not separately identify equipments by mission, and (3) final design release for the Apollo-Saturn 504 Mission is not scheduled until March 1966. It should be noted that GOSS is not included in this section and that GSE is indirectly reported.

The ensuing paragraphs (4.2 through 4.7) will treat the reliability status of each of the stages and modules in turn. Launch Complex 39 is briefly discussed in paragraph 4.8 and a mission analysis based on apportionments is presented in paragraph 4.9. Paragraph 4.1 summarizes the findings.

4.1 GENERAL (SUMMARY)

4.1.1 Program. Figure 4-1 summarizes the status of the Apollo-Saturn MLL Mission Reliability Program. Since hardware representative of Apollo-Saturn 504 Mission is largely in the design and development phases, comparison has been made to paragraph 3.2.2 (Conceptual/Feasibility Phase), paragraph 3.2.3 (Design Phase), and paragraph 3.2.4 (Development Phase) of NASA Document NPC 500-5.

Figure 4-1a summarizes the status of additional significant Quality Assurance Program elements specified in NPC 200-2.

Figure 4-2 summarizes the degree to which launch vehicle contractual reliability requirements were being implemented as of May 1965. A more detailed presentation of the data is contained in each of the stage discussions.

The degree to which Command Service Module and Lunar Excursion Module reliability requirements are being implemented was not available.

NPC 500-5 PROGRAM ELEMENTS	Phase	F-1	S-IC	S-II*	S-IVB*	IU	CSM SLA LES	LEM
Reliability Goals	Conceptual Phase	C	C	C	C	C	C	C
R&QA Plans	Conceptual Phase	I	I	I	I	I	C	I
Reliability Prediction	Conceptual Phase	C	C	C	C	C	C	C
Apportionments	Design Phase	I	C	C	C	I	C	C
FMEA's	Design Phase	I	I	C	C	I	C	C
Specification Reliability Requirements	Design Phase	C	I	I	C	I	C	I
Mission Profile	Design Phase	I	I	U	I	U	I	I
Human Engineering and Maintainability	Design Phase	C	I	C	I	I	U	I
Parts and Materials	Design Phase	I	I	I	I	I	U	U
Test Requirements	Design Phase	C	C	C	C	U	I	I
Change Control	Development Phase	C	I	I	C	C	C	I
Critical Items	Development Phase	I	I	I	I	U	I	I
FR's and Corrective Action	Development Phase	I	I	I	I	I	I	I

*Refer to Figure 3-3 for J-2 Engine Information

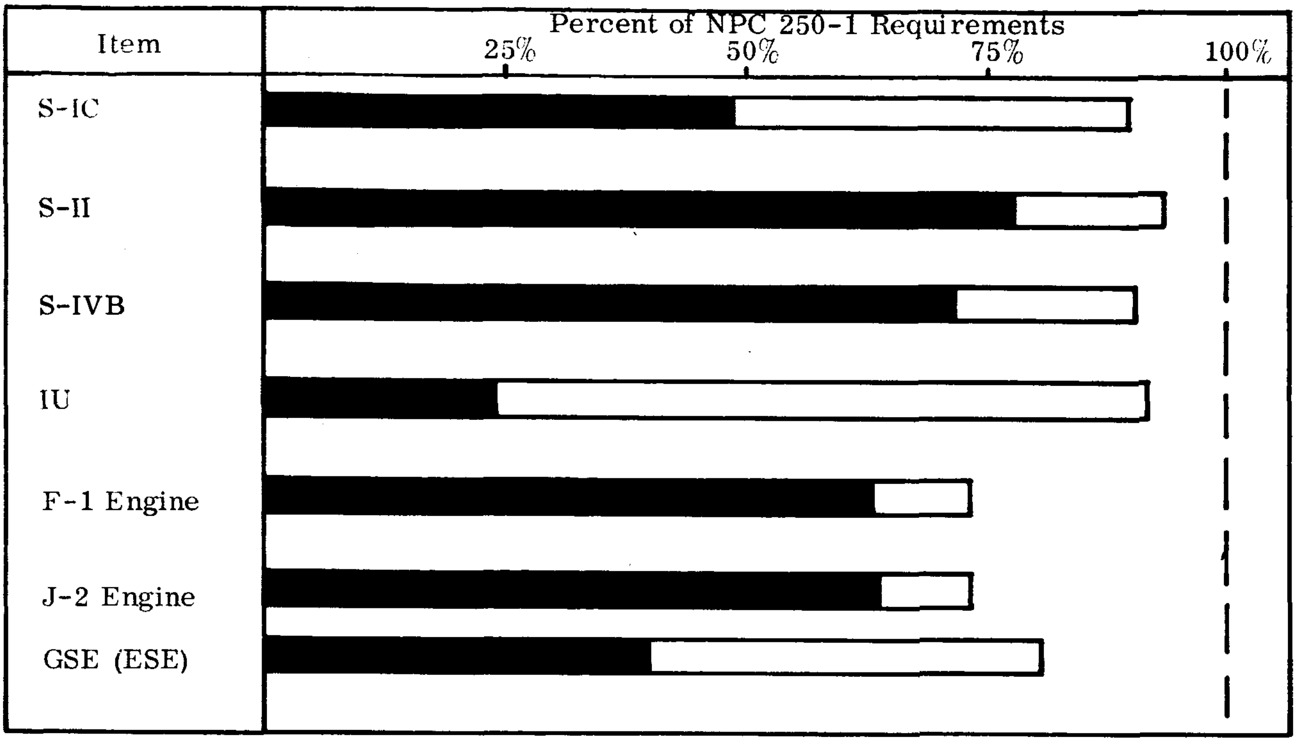
Legend:
I = Initiated
C = Complete
U = Status Unknown

Figure 4-1. Apollo-Saturn MLL Reliability Program Status

NPC 200-2 PROGRAM ELEMENTS	Phase	F-1	J-2	S-IC	S-II	S-IVB	IU	CSM SLA LES	LEM	G&N
Quality Requirements	Fabrication Phase	C	C	C	C	C	C	C	C	C
GA Quality Program Plan	Fabrication Phase	U	U	C	U	U	U	I	C	I
End Item Test Plan	Fabrication Phase	U	U	U	C	U	U	I	U	U
Contractor Audit by Center	Fabrication Phase	I	I	I	I	I	I	I	I	I
GA Audit by Center	Fabrication Phase	U	U	U	U	U	U	U	U	U
Quality Status List	Ground Test Phase	U	U	U	I	U	I	I	U	I
Contractor Qual Status Rpts	Ground Test Phase	C	C	U	C	U	C	C	C	C
GA Quality Status Rpts	Ground Test Phase	I	I	U	U	U	U	I	I	I

Legend:
I = Initiated
C = Complete
U = Status Unknown

Figure 4-1a. Apollo-Saturn MLL Quality Assurance Program Status



Note: The degree of implementation may in some instances be greater than represented. MSFC has rated all areas of insufficient information as zero.

Legend:

(1) NPC 250-1 Elements Contractually required

(2) NPC 250-1 Elements being Implemented

Figure 4-2. Launch Vehicle Contractual versus Implemented Requirements (25)

Mission Analysis. Quantitative reliability analyses, based upon center/contractor documented reliability apportionments, identify inconsistencies in the apportionments (see paragraph 4.9). The reliability apportionment status for the S-IC stage reported by Boeing is consistent with the 0.95 reliability goal for the S-IC Stage. However, Boeing bases this apportionment on a reliability value of 0.999 for each of the F-1 engines. The NASA contract specifies a reliability goal of 0.99 for each engine. Similar inconsistencies appear in the S-II and S-IVB stages (see paragraph 4.9).

Manned Lunar Landing (MLL) Mission Success and Crew Safety Estimates, based on apportionments, are 0.73 and 0.96 respectively. These are not in consonance with the Apollo Program Specification goals of 0.90 and 0.999.

4.1.2 Program Accomplishments. Major accomplishments during this period include:

- Successful "leapfrogging" of the S-IC-T three-engine firing program. This achievement permits an accelerated and more comprehensive S-IC-T firing program of approximately nine months duration during which five-engine reliability can be more completely established.
- Completion of the initial Single Point Failure Analysis for the S-IC Stage.
- Completion of initial FMEA's on all stages and modules of the Apollo-Saturn 500 Series.
- Successful completion of the 339-hour vacuum endurance test by the CSM fuel cell.
- Resolution of the Unit Logic Device problem which had been causing Instrument Unit failures.

4.1.3 Problems. Typical Apollo-Saturn 500 Series problems are:

- GSE reliability information is extremely limited. Although this has long been a problem on large programs, the lack of such information on Apollo prevents reliability assessments of those Apollo-Saturn 500 Series equipments which are tied to GSE.
- GOSS reliability status is indeterminate.
- Qualification Test completion dates are slipping and the term "Qualification" is being replaced by other nomenclatures; e.g., "Qual Like" and "Certification." Slippage of the test completion dates indicates pressure will mount to fly unqualified hardware whose reliability is unknown.

4.2 S-IC STAGE - SATURN V

4.2.1 General. During this report period the S-IC Stage was in the ground test 'captive firing' phase. Reliability effort was directed toward establishing the reliability of the design.

4.2.2 Accomplishments. Reliability milestone activities are depicted in Figure 4-3. Milestone activities beyond 1965 were not available.

Contractor progress toward implementation of contractually required Reliability Program elements is shown in Figure 4-4.

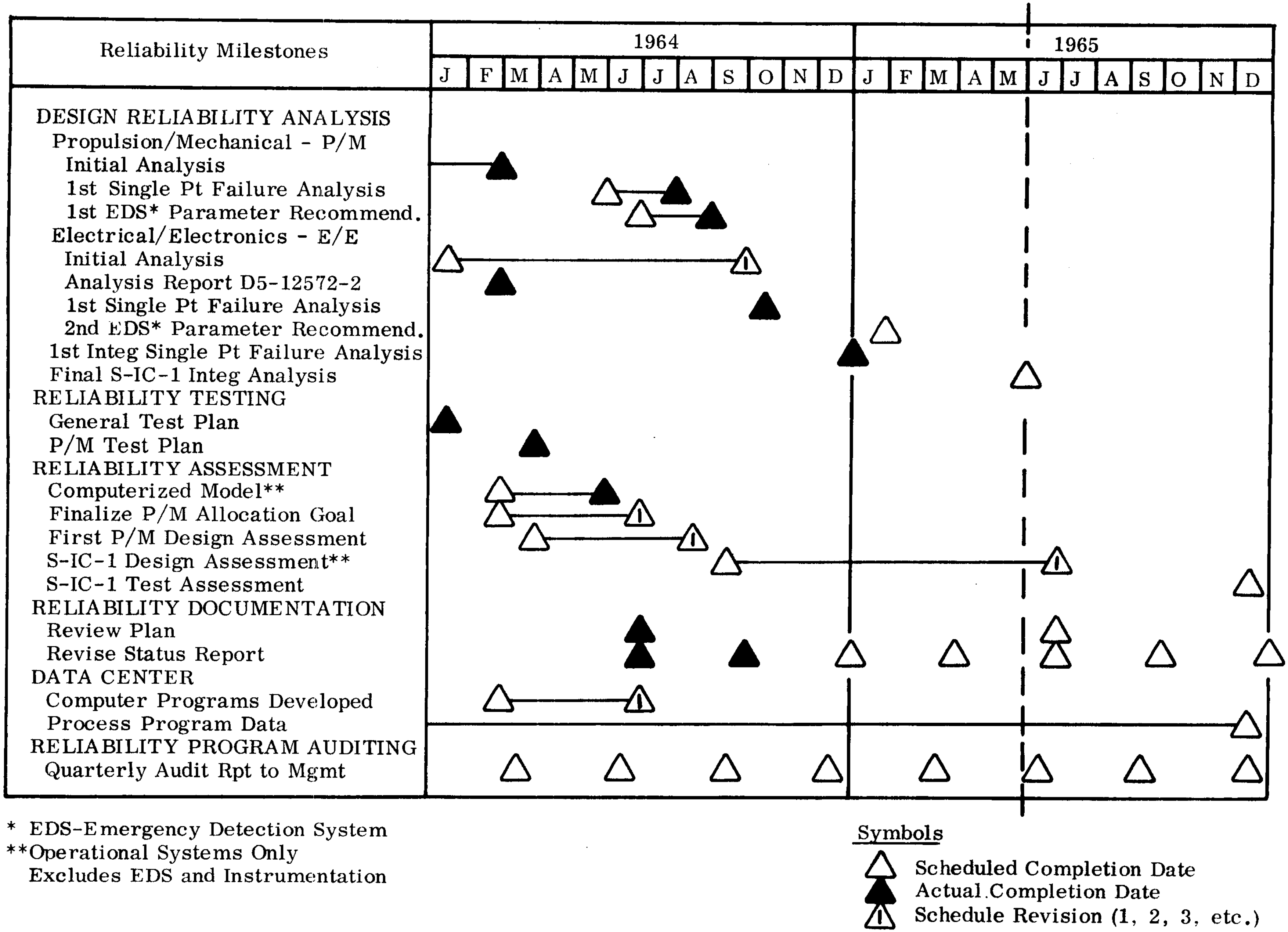
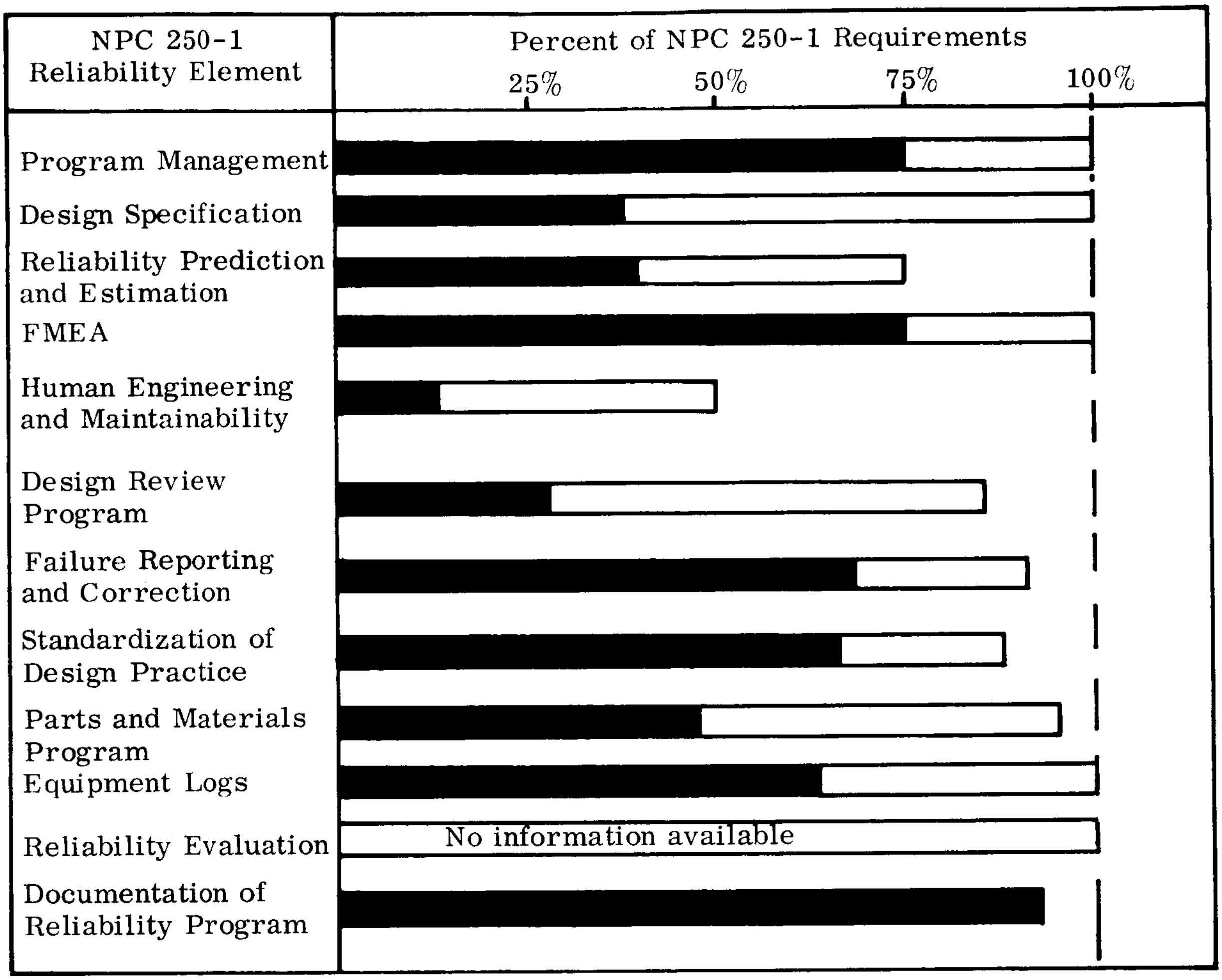


Figure 4-3. S-IC Stage Reliability Program Milestones (104)



Note: The degree of implementation may in some instances be greater than represented. MSFC has rated all areas of insufficient information at zero.

NPC 250-1 Elements Contractually Required

NPC 250-1 Elements Being Implemented

Figure 4-4. S-IC Stage Contractual versus Implemented Requirements (25)

Other major S-IC Reliability Program accomplishments during this period include: (107) (25) (101)

- Successful "leapfrogging" of the S-IC-T three-engine firing program. This achievement permits an accelerated and more comprehensive S-IC-T program.
- Completion of the initial Single Point Failure Analysis for the S-IC stage.
- Establishment of reliability goals and apportionments.

- Boeing reports that the S-IC propulsion-mechanical system reliability goals have been achieved.

- FMEA's have been initiated.

- Initiation of S-IC "Engine Out" Studies. An "Engine Out" capability on Saturn V increases reliability by 12.5 percent.

- Critical hardware has been defined. The S-IC critical hardware is listed in Figure 4-5.

Subsystem	Type of Loss	Remarks
Fuel Pressurization	LOX tank rupture Engine explosion from cavitation Fuel tank collapse	Duct gimbal joints contribute 98.4 percent of the criticality.
Fluid Power	Fire or explosion Thrust vector control loss	Duct gimbal joints contribute 82 percent of the criticality; gaskoseals and flexible metal hoses each contribute 9 percent.
Fuel Delivery	Fire or explosion Premature engine shutdown	Duct gimbal joints contribute 50 percent of the criticality, fuel prevalves 28 percent, and sliding presure volume compensation joints 21 percent.
LOX Delivery	Fire or explosion Premature engine shutdown	Duct gimbal joints contribute 58 percent of the criticality, LOX prevalves 19 percent, sliding joints 11 percent, and pressure volume compensators 9 percent.
Retrorocket	Improper separation Rocket explosion	
LOX Pressurization	Fire or explosion	Duct gimbal joints contribute 94 - 95 percent of the criticality.
Control Pressure		Seven solenoid control valves contribute 100 percent of the criticality
Engine Purge and Prefill	Fire or explosion	Pressure regulator is most critical item.

Figure 4-5. Critical S-IC Stage Hardware Items (106)

4.2.3 Problems

- Duct gimbal joints are a critical item and currently represent a major source of failure.
- The assessment program cannot be completed unless GSE design analyses data requested by Boeing is provided (25).
- Full implementation of the "Parts Selection and Control Program, Saturn S-IC (D5-11372)" is being held up pending approval of a contract modification (25).

4.3 S-II STAGE - SATURN V

4.3.1 General. The S-II stage is in the 'captive firing' phase. A reliability program has been established. Reliability program accomplishments and problems are described in paragraphs 4.3.2 and 4.3.3. Fabrication of the S-II stage hardware for Apollo-Saturn 504 has not been initiated.

4.3.2 Accomplishments. Reliability program effort during this period has been keyed to design and development activities. Contractor progress toward implementation of contractual reliability requirements is portrayed in Figure 4-6 (25).

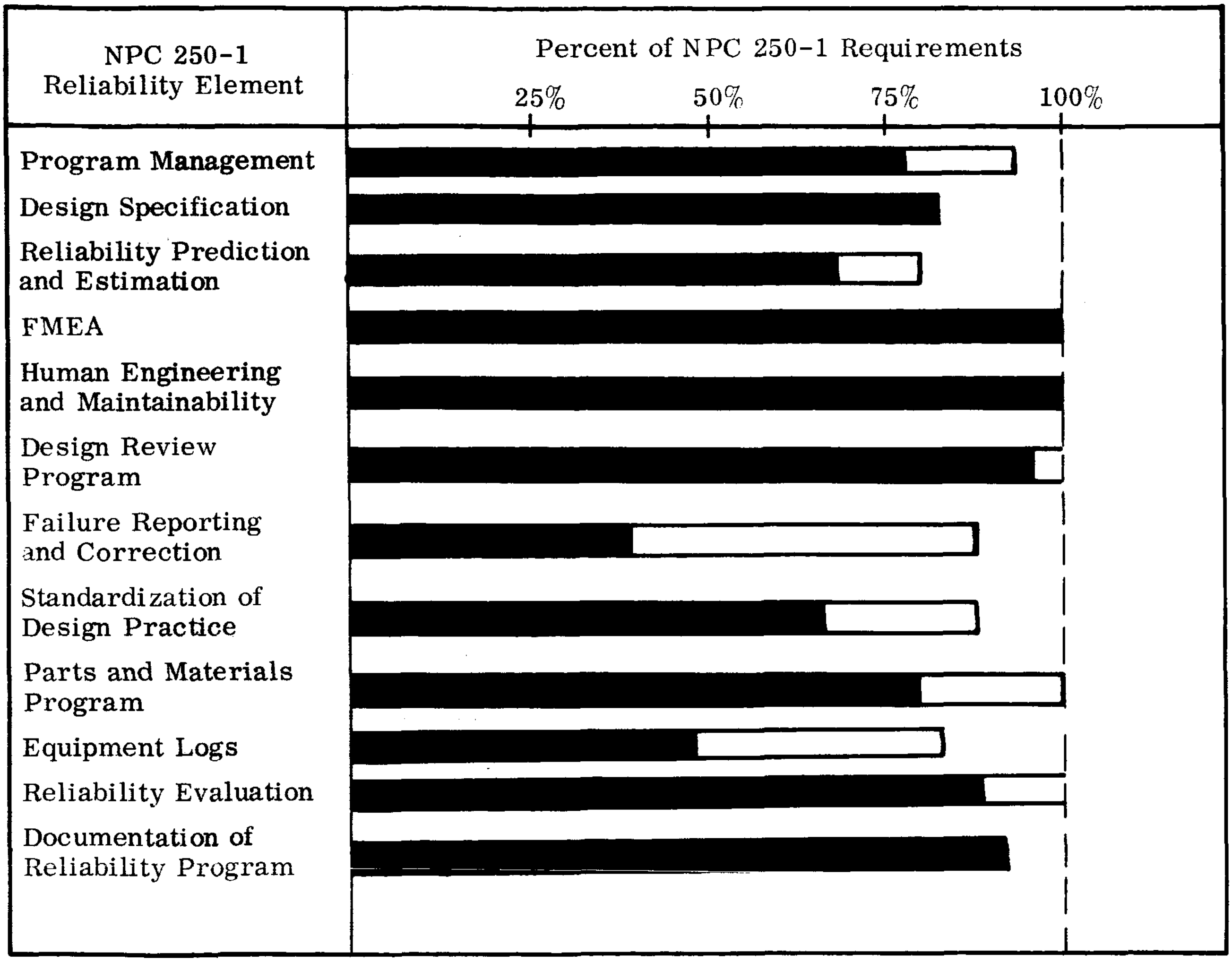
A successful five-engine cluster ignition firing was accomplished on 24 April 1965.

4.3.3 Problems

- Qualification Tests are behind schedule (84).
- Definition of what constitutes a failure has not been established; i.e., MSFC and NAA/S&ID have not agreed on what constitutes a failure.

4.4 S-IVB STAGE-SATURN V

4.4.1 General. Reliability and quality activity pertinent to earlier S-IVB vehicles is reported in Section 3 of this report. The accomplishments and problems listed below are intended to reflect S-IVB/V activity.



Note: The degree of implementation may in some instances be greater than represented. MSFC has rated all areas of insufficient information at zero.

NPC 250-1 Elements Contractually Required

NPC 250-1 Elements Being Implemented

Figure 4-6. S-II Stage Contractual versus Implemented Requirements (25)

4.4.2 Accomplishments. Contractor progress toward implementation of contractually required Reliability Program elements is shown in Figure 4-8.

- A full duration battleship firing was satisfactorily completed on 31 March 1965.
- Flight Critical Item Design Specifications and Flight Critical Item Test Requests have been reviewed by Douglas Reliability.
- A reliability math model has been established.

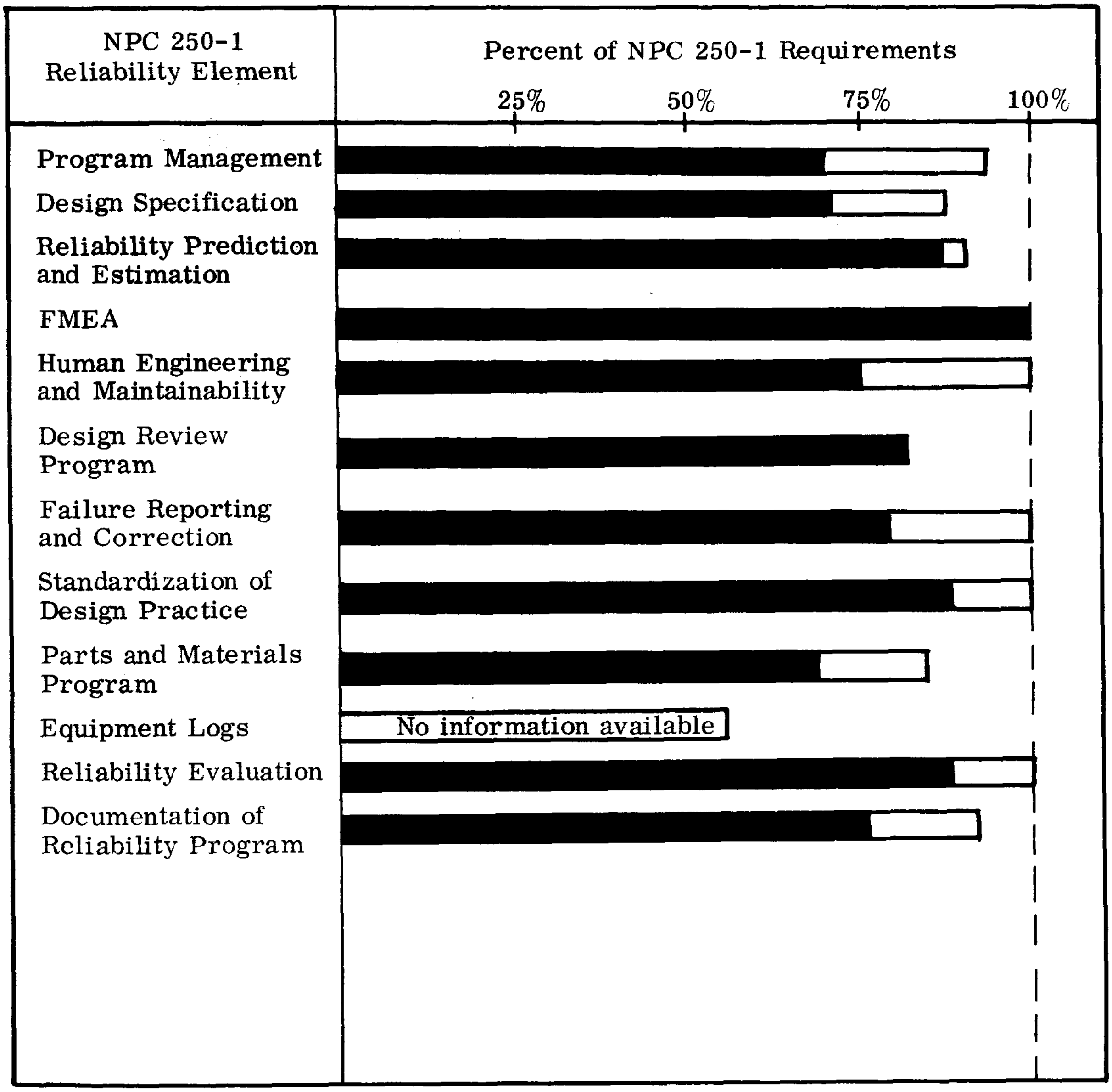
- Initial FEA's have been completed.
- Criticality rankings have been prepared, as shown in Figure 4-7.
- Traceability has been invoked.
- A Douglas-approved parts list for the S-IVB has been established.

4.4.3 Problems

- Propellant tank corrosion.
- J-2 start problems.
- Specifications contain no requirements for reliability demonstration tests.

Rank	Item	Subsystem
1	Selector Switch	Electrical
2	Engines, Auxiliary Propulsion Attitude Control, 150-Pound Thrust (8)	Flight Control
3	Modules, Helium Fill (2)	Flight Control
4	Electronic Assembly, PU	Propellant Utilization
5	Pump, Hydraulic, Auxiliary Motor Driven	Auxiliary Power Supply
6	Engines, Auxiliary Propulsion 1750-Pound Thrust (2)	Flight Control
7	Cable Assembly (Electrical Distribution)	Electrical
8	Sequencer Mounting Assembly	Electrical
9	Separator, Vent, Zero Gravity	Propulsion
10	Pump, Hydraulic, Thermal Isolator Assembly	Auxiliary Power Supply

Figure 4-7. Ten Most Critical Items (Excluding J-2 Engine) S-IVB/V Stage



Note: The degree of implementation may in some instances be greater than represented. MSFC has rated all all areas of insufficient information as zero.

NPC 250-Elements Contractually Required

NPC 250-1 Elements Being Implemented

Figure 4-8. S-IVB Stage Contractual versus Implemented Requirements (25)

4.5 INSTRUMENT UNIT - SATURN V

4.5.1 General. Activity on the Instrument Unit for the Apollo-Saturn MLL Mission is in a transition phase from total MSFC responsibility to total

IBM responsibility on S-IU-504. The activity on the IU for the Saturn IB launch vehicle is covered in Section 3.

Since the IU equipment envisioned for the Saturn V launch vehicle is similar (and in many cases identical) to equipment built for the Saturn IB launch vehicle, primary attention is focused on the Saturn IB series mission-essential hardware. A "peripheral vision" overview is given to the balance of the 500 Series hardware which will be flown on the 200 Series flights but which is not considered mission-essential on the 200 Series flights.

System engineering activities specifically concerning the 500 Series flights will receive primary attention about the end of 1965. These activities include completion of test specifications, updating of functional block diagrams, failure mode and effects analyses, etc.

The IBM contract (NAS 8-14000) and the IBM Reliability Program Plan are in process of being revised to reflect the MSFC apportionment of 0.992 as the IU probability of mission success for an Apollo-Saturn MLL Mission of 6.8 hours. IBM, in turn, will apportion this goal downward to the component level.

4.5.2 Accomplishments. Contractor progress toward implementation of contractually required Reliability Program elements is shown in Figure 4-9.

Persistent failures affecting the Launch Vehicle Data Adapter (LVDA) are reported solved.

4.6 COMMAND SERVICE MODULE (CSM)

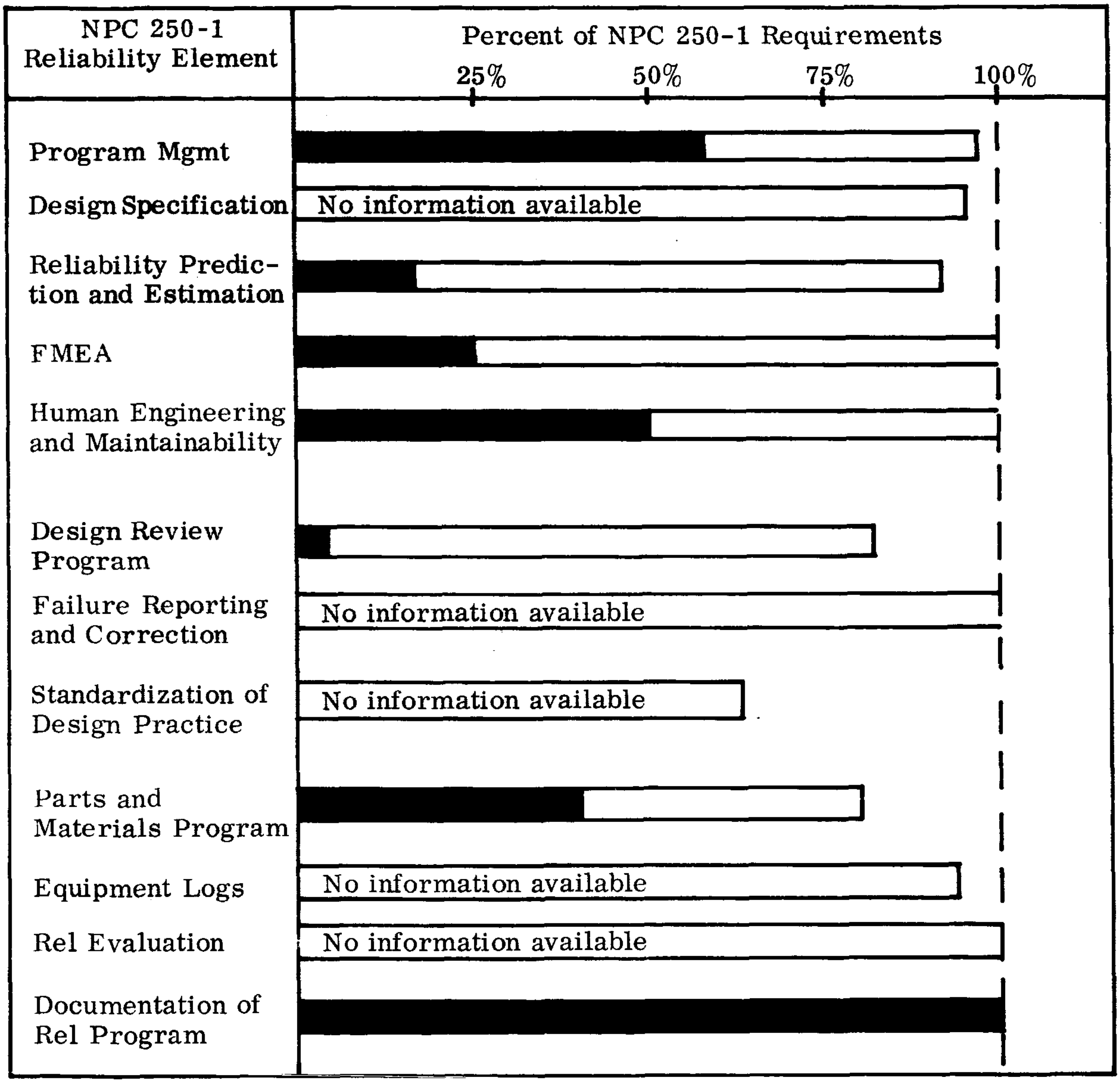
4.6.1 General. This section is based upon CSM reliability activities occurring during the first half of calendar year 1965. Major events, problem areas, and status are discussed as they relate to the CSM R&QA program. The CSM test and flight articles included within this discussion are identified in Figure 4-12.

4.6.2 Accomplishments. Reliability and quality milestone activities are depicted in Figure 4-10.

Reliability Modeling

- A 'top down' functional assessment model was developed during the reporting period. This model, which uses standard statistical methods, provides a measure of the probability of successfully performing critical mission functions at the 60 percent confidence level.

- A follow-on activity is currently underway to establish a reliability growth trend baseline curve for the first MLL mission. The pre-



Note: The degree of implementation may in some instances be greater than represented. MSFC has rated all areas of insufficient information as zero.

NPC 250-1 Elements Contractually Required

NPC 250-1 Elements Being Implemented

Figure 4-9. Instrument Unit Contractual versus Implemented Requirements (25) liminary assessment for crew safety is scheduled for completion by 15 May 1965 (70).

Qualification Test Status

- Qualification test program is summarized in Figure 4-11.
- The second CSM fuel cell module successfully completed the 339-hour vacuum endurance test on 9 April 1965. At the end of the endurance test, the module produced 1452 watts at 27 volts while the minimum specification requirement is 1420 watts at 27 volts. The emergency requirements for the same mission time is approximately 2150 watts at 20.5 volts minimum and the module produced 2176 watts at 24 volts.

Failure Reporting and Corrective Action

- A system was developed by NAA/S&ID for reporting and displaying failure summaries for management visibility. Monthly and quarterly failure volume is reported by subcontractors, suppliers, and NAA/S&ID. The failure information is displayed for the major subsystems, certain boilerplates, Block I spacecraft, and the total program (70).

4.6.3 Problems

Reliability Modeling. Current CSM reliability design goals for LOR are based on NAA/S&ID definition of mission success. If LOR reliability design goals are aligned to NASA's definition of mission success (AMPTF Design Reference Mission Profile), higher reliability would be required for those subsystems that operate throughout the entire mission. The facts relating to this problem were presented to NASA/MSC on 10 March 1965 (70).

FMEA Status. FMEA's are not complete for Block II equipment configurations. The FMEA status for CSM subsystems is shown in Figure 4-13.

G&N Computer Operating Time. G&N computer operating time, specified by the latest AMPTF Design Reference Mission Profile, precludes meeting the reliability objectives of the combined electronics subsystem. A study is in progress to trade-off computer times between the G&N and SCS for lunar orbit operation (70).

Qualification Test Status. Burst test failures, SPS helium tanks, occurred on Units 3 and 4. Both units failed well below proof-pressure requirement of 5867 psig. As a result, two additional helium tanks have been added to the qualification test program (70).

4.6.4 Manufacturing Performance. Figure 4-14 indicates the trend in quality performance of the prime contractor during the manufacturing cycle.

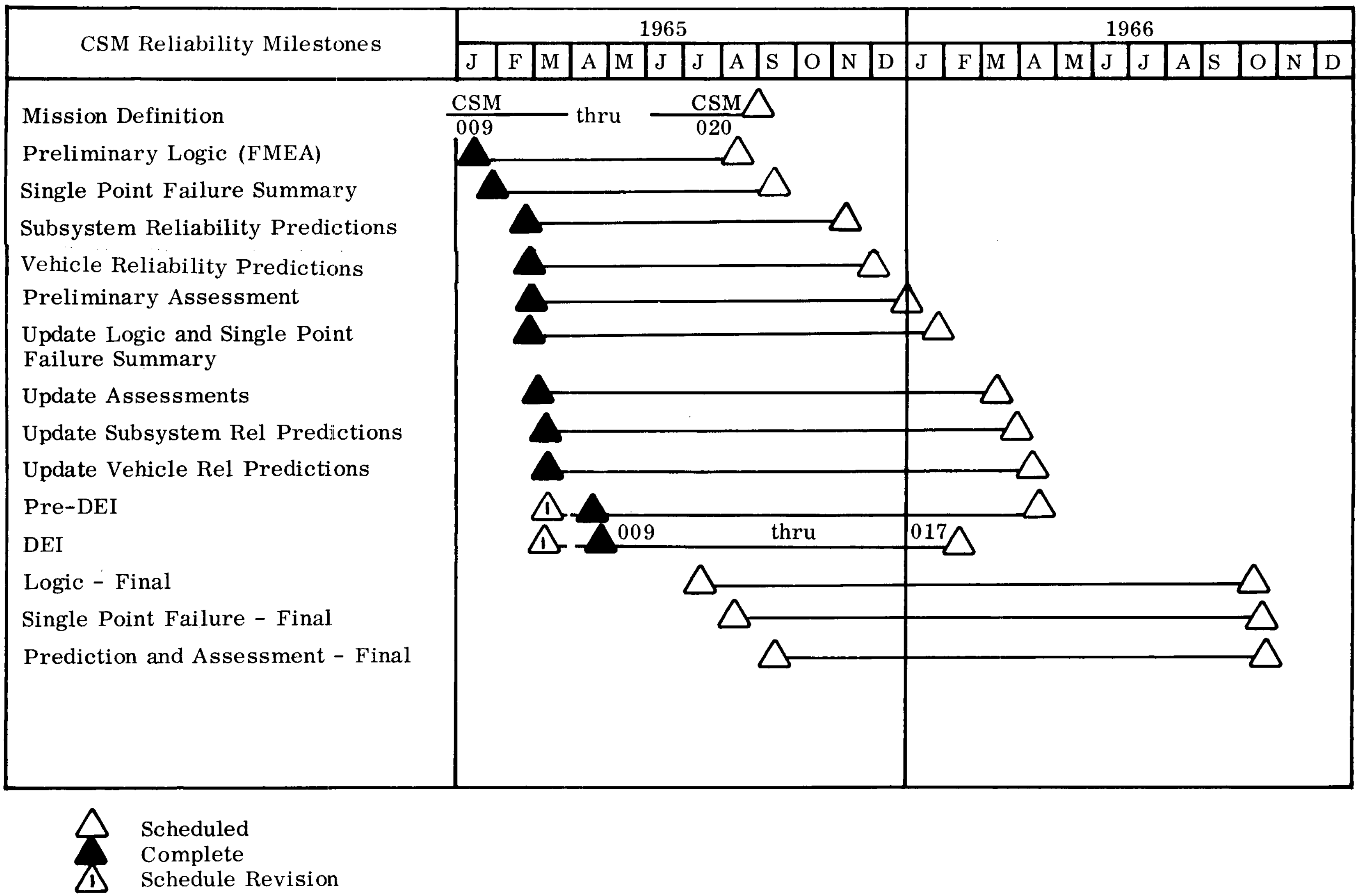


Figure 4-10. CSM Reliability Program Milestones

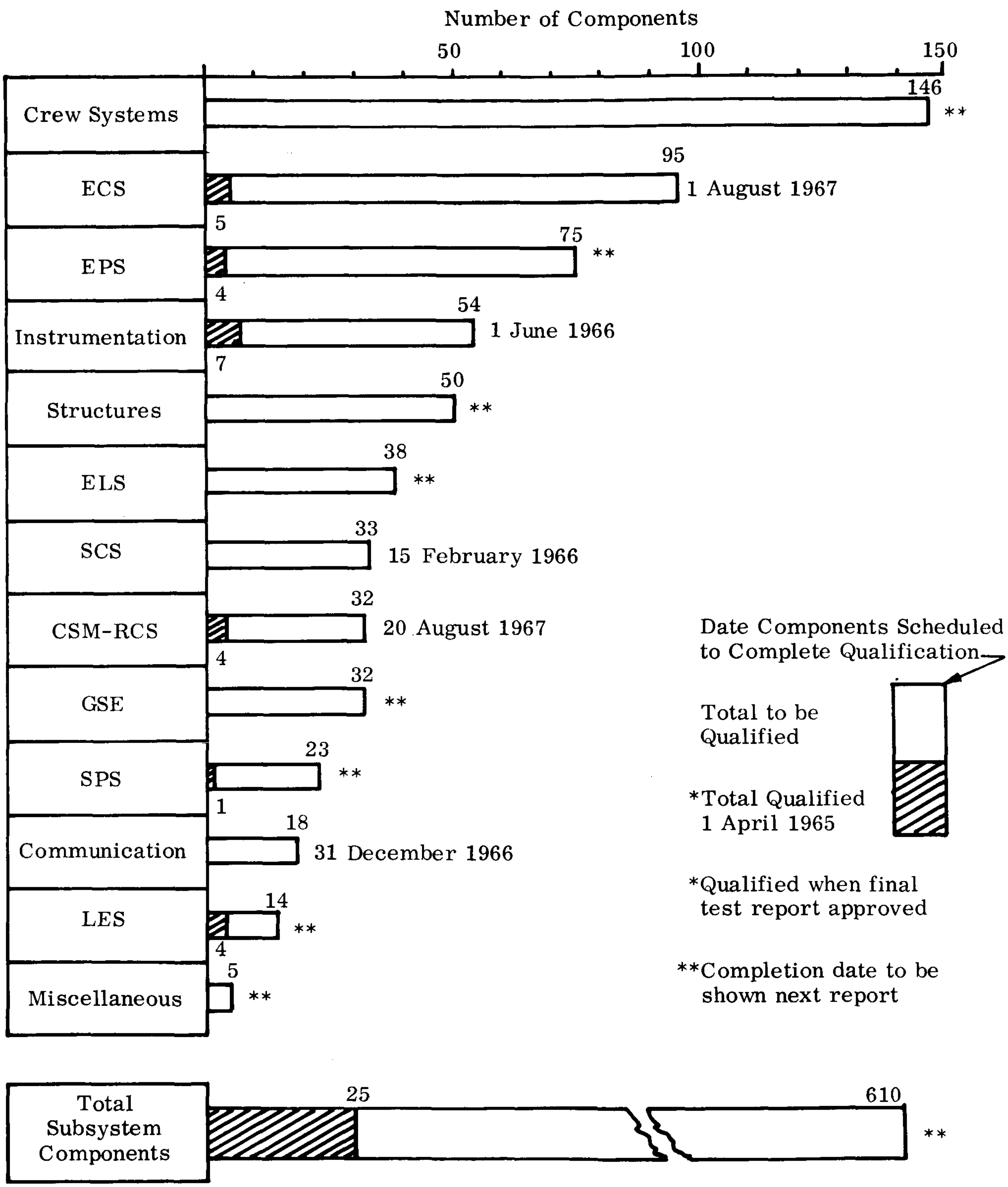


Figure 4-11. Block II CSM Component Qualification Status by Subsystem

ARTICLE/ VEHICLE	MISSIONS	SITE	STATUS/COMMENTS	SCHEDULE	
				START	FINISH
BP-1	CM for land/water impact tests	Downey	Complete	10/62	3/65
BP-2	CM for land/water impact tests	Downey	On Schedule	10/62	5/65
BP-6A and 19	CM for parachute recovery tests	Downey	On Schedule	2/63	11/65
BP-14	House Spacecraft No. 1	Downey	On Schedule	6/64	-
BP-25	CM for water recovery and handling equipment tests	MSC	Completed	8/62	3/64
BP-27	Modal and dynamic tests	MSFC	MSC portion completed; MSFC on schedule	9/64	11/65
BP-28	CM landing impact tests	Downey	Five months slippage	9/64	7/66
BP-29	CM flotation and recovery tests	MSC	On schedule	4/65	11/65
SC001	SM for propulsion tests	WSMR	One-month slippage	2/65	10/66
SC004	Static tests	Downey	One and one-half months slippage, SM delivered to Downey 7 May 1965	4/65	9/66
SC006	House Spacecraft No. 2	Downey	Cancelled	9/65	5/67
SC007	Acoustic water impact and post-landing tests	Downey	On schedule	5/65	8/66
SC002A	CM for land impact tests	Downey		12/65	7/66
SC008	Thermal vacuum tests	MSC		1/66	1/67
2H1	House Spacecraft No. 3 (manned integrating systems checkout)	Downey		6/66	12/66
2TV1	Thermal vacuum tests	MSC		2/67	6/68
2S1	Modal, acoustics, post-landing tests	Downey		9/66	-

Figure 4-12. Major CSM Test Article and Flight Vehicle Status

ARTICLE/ VEHICLE	MISSIONS	SITE	STATUS/COMMENTS	SCHEDULE	
				START	FINISH
2S2	Static structural tests	Downey		8/66	8/67
SC017	Unmanned supercircular re-entry flight - A501	ETR			
SC020	Unmanned supercircular re-entry flight - A502	ETR			
SC102	Earth orbital flight - A503	ETR			

Figure 4-12. Major CSM Test Article and Flight Vehicle Status (Cont.)

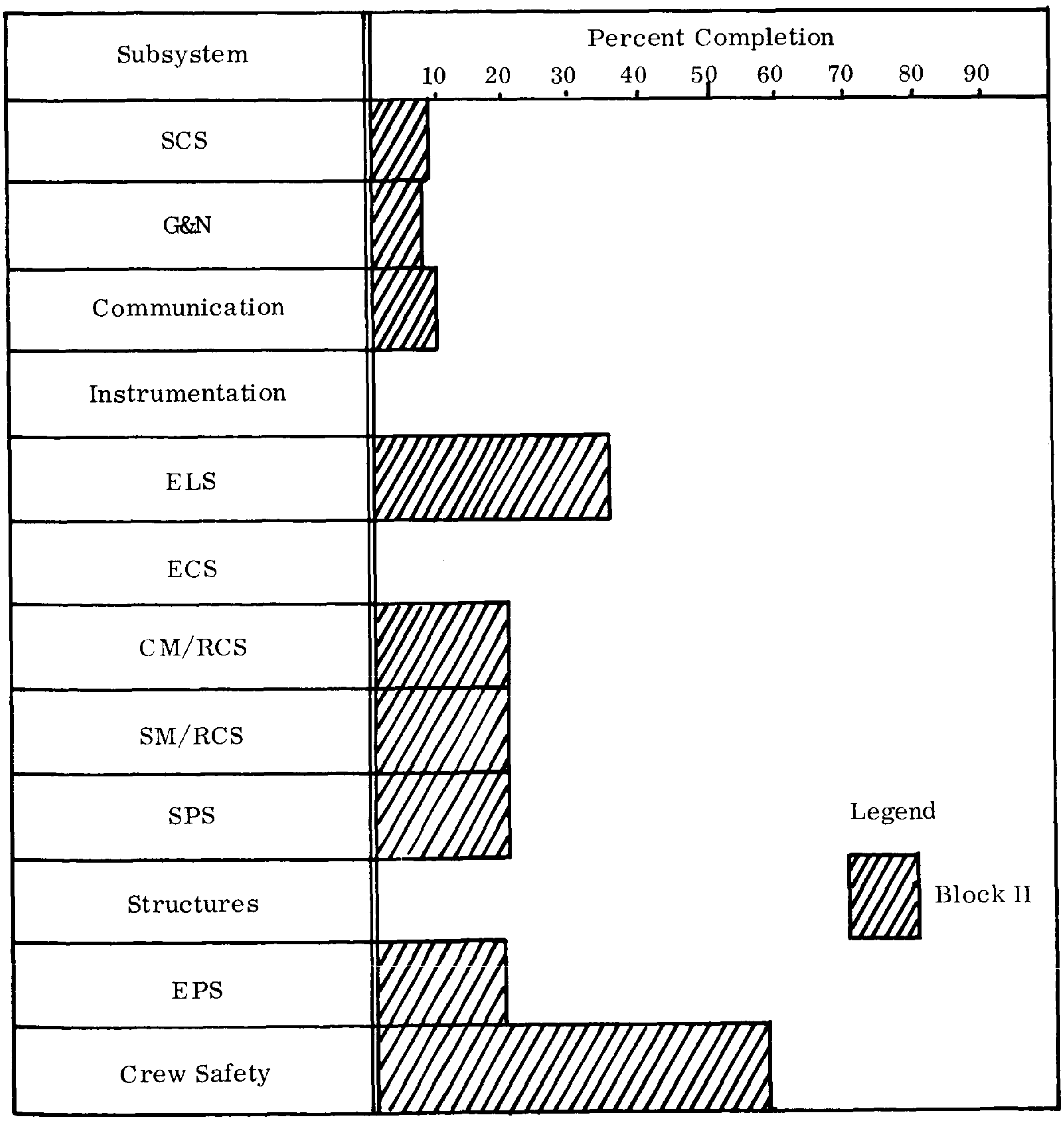


Figure 4-13. CSM Subsystem Failure Mode Effect Analysis Status

This is measured by determining the defects noted at the prime contractor's facilities per thousand manufacturing standard hours (114).

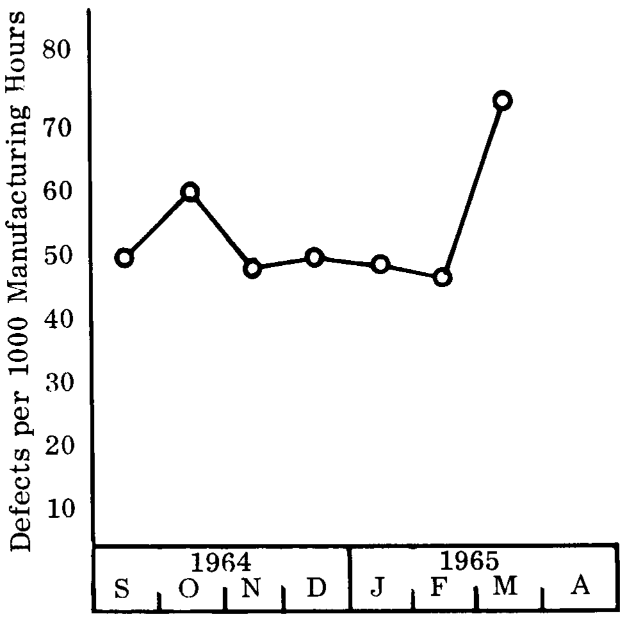


Figure 4-14. G&N Manufacturing Defects

4.7 LUNAR EXCURSION MODULE (LEM)

4.7.1 General. This section is based on LEM reliability and quality activities occurring during the first half of calendar year 1965. Major events, problem areas, and status are discussed as they relate to LEM R&QA program. The LEM reliability program reflects the requirements of NPC 250-1 and, in general, appears to provide an orderly approach to assuring crew safety and Manned Lunar Landing (MLL) Mission success.

4.7.2 Accomplishments. Reliability and quality program milestone activities are depicted in Figure 4-15.

Reliability Modeling

- LEM subsystem reliability models have been updated to incorporate the latest design configurations and the AMPTF Design Reference Mission Profile (91).
- GAEC is preparing a LEM reliability assessment plan and completion of the plan is scheduled for the first half of calendar year 1965 (97).

FMEA Status

- FMEA's have been initiated on all LEM subsystems and have progressed beyond the point of defining equipments, functions, and failure modes (97).

- Initial report on LEM single point failure analysis was completed by GAEC and issued in the document entitled "Potential Single Point Failure Analysis," LED-550-40, 1 December 1964.

Tradeoff Studies

- As a result of the battery versus fuel cell weight reliability study, decision was made to use the all-battery configuration (95) (97).

  The GAEC descent stage "All Battery Reliability Analysis" revealed that a four-battery system (against proposed five- or six-battery configuration) represented the simplest design and an acceptable mission success reliability (99).

  Four batteries will be used in the descent stage and two batteries will be used in the ascent stage. The Eagle Pitcher Company was selected to develop these batteries for the LEM electrical power system.

Qualification Test Status

- Test article and flight vehicle status is presented in Figure 4-16.

Failure Reporting and Corrective Action

- GAEC LEM failure data is reported to MSC on magnetic tape. Failure summaries for failure reporting and corrective action status were not available for this report (94).

4.7.3 Problems

FMEA Status. Major problems revealed during preliminary FMEA analyses are described as follows:

- The RCS functional FMEA revealed several problem areas wherein failure would have a series effect on mission success and crew safety reliability (97). These include the following items:

  a. Explosive actuated helium squib valve.

  b. Helium tank relief valve.

  c. Propellant tank bladders.

  d. Ascent interconnect.

  e. Helium pressure regulator deficiencies.

- GAEC reports that preliminary evaluation of the communication subsystem FMEA's revealed a series (97) lack of malfunction detection devices.

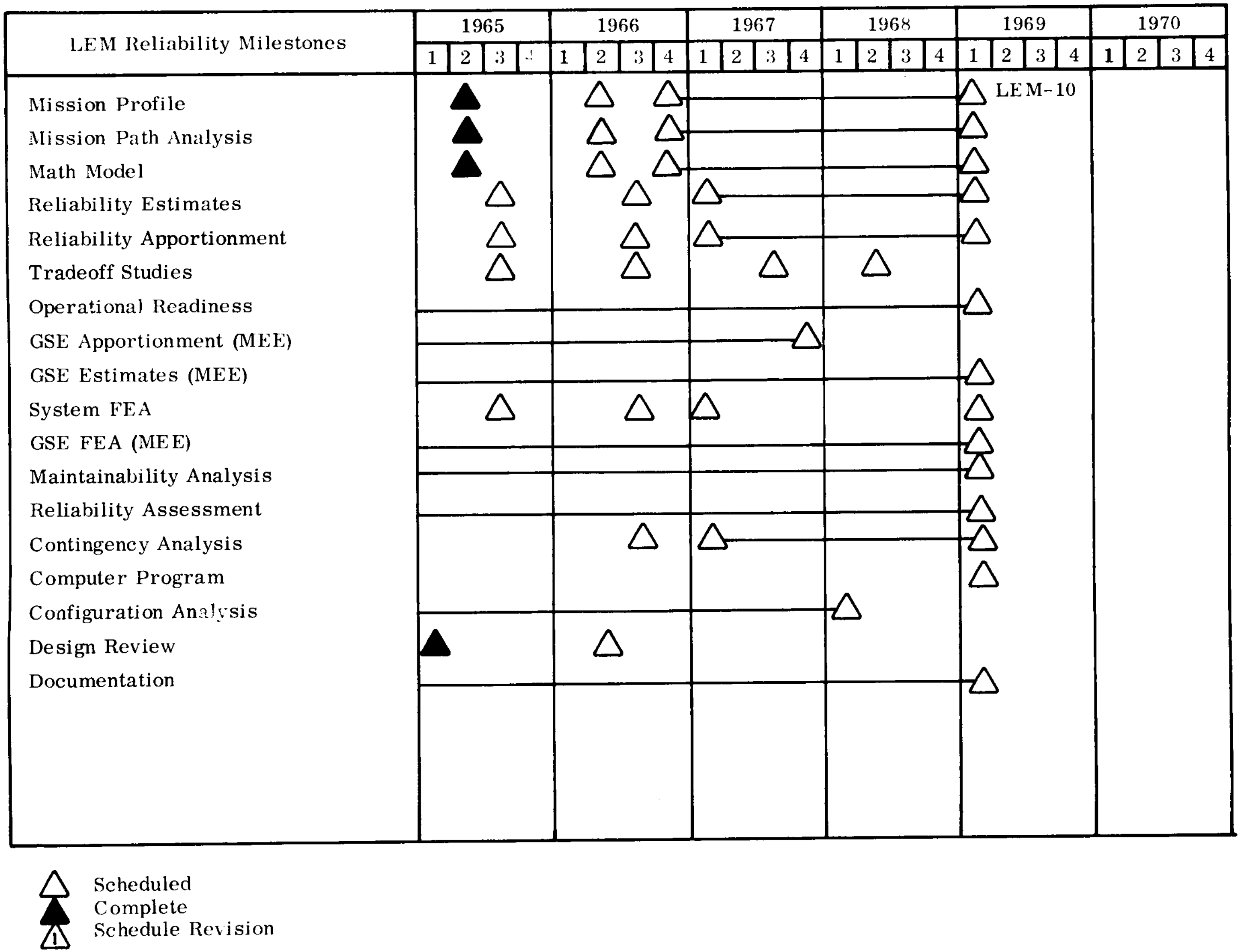


Figure 4-15. Reliability Program Milestones

ARTICLE/ VEHICLE	MISSION	SITE	STATUS/COMMENTS	SCHEDULE	
				START	FINISH
HA-1	Ascent engine cold flow tests	GAEC	Cold flow testing - 15 weeks slippage	-/64	11/65
HA-2	Ascent engine firings	Bell		11/65	3/66
HA-3	Ascent engine drop tests including FITH	WSMR	Test firings started mid-April 1965 six weeks slippage. Two successful firings to date.	-/64	7/66
HA-4	Ascent engine firings	ADEC	Structure near completion - schedule for shipment to AEDC in May 1965	10/65	1/66
HD-1	Descent engine cold flow tests	GAEC		-/64	12/65
HD-3	Descent engine drop tests including FITH	WSMR		12/65	3/66
HD-4	Descent engine firings	ADEC	Shipped to AEDC in March - tests scheduled for January 1966	1/66	3/66
PD-1	Descent engine firings	WSMR	12 weeks slippage	3/64	10/66
PA-1	Individual and integrated ascent engine and RCS tests	WSMR	12 weeks slippage	3/64	3/66
PD-2	Descent engine firings	WSMR	9 weeks slippage	4/64	7/66
FC-1	Simulated vehicle dynamic tests in support of individual LEM's	GAEC		10/65	-
KTA-1	House Spacecraft No. 1 - electronic subsystem integration	GAEC	ESI rig in fabrication stage, Phase 1 tests to start August 1965	9/65	-
LTA-2	Dynamic test vehicle for Saturn IB and V	MSFC	Arrived at MSFC 18 February 1965 - on schedule	12/64	10/65

Figure 4-16. Major LEM Test Article and Flight Vehicle Status

ARTICLE/ VEHICLE	MISSION	SITE	STATUS/COMMENTS	SCHEDULE	
				START	FINISH
LTA-3	Structural test vehicle	GAEC		7/65	10/65
LTA-4	House Spacecraft 2 - electrical support LEM-4 and subsystem vibration tests	GAEC	Indications are that this article may be eliminated	1/66	-
LTA-5	Propulsion test vehicle	WSMR		10/65	-
LTA-8	LEM and LEM/CSM thermal vacuum tests	MSC	Test plan in preparation	8/65	-
LTA-10	Static structural test vehicle	Tulsa	DEI - conducted on 23 April 1965 - shipped to Tulsa on 27 May 1965	2/65	-
TM-2	Thermal vacuum tests	GAEC	In fabrication	5/65	1/62
TM-5	Landing stability tests	GAEC	In fabrication	3/65	1/66
FTA-1	LEM compatibility with Saturn V launch environment demonstration A501	KSC	Indications are that this vehicle may be eliminated	5/66	-
FTA-2	LEM compatibility with Saturn V launch environment demonstration	KSC	Indications are that this vehicle may be eliminated	9/66	-
LEM-1	Unmanned LEM propulsion in earth orbit and fuel propellant A206	KSC	Detail test plan complete - six months projected slippage in delivery per 32A schedule	11/65	-
LEM-2	Manned LEM rendezvous and docking in earth orbit A207	KSC		3/66	-
LEM-3	Manned LEM, lunar mission simulation in earth orbit A503	KSC		5/66	-
LEM-4	Manned LEM - translunar - A504	KSC		9/66	-

Figure 4-16. Major LEM Test Article and Flight Vehicle Status (Cont.)

Qualification Test Status

- The RCS oxidizer tank bladders have been reported as incapable of meeting specification requirements. GAEC states that tank failure rates have increased as a result of a MSC directed change from a 3 mil, 3 ply bladder design to a 6 mil, 1 ply bladder design (91).

- Test schedule slippage has been identified in the LEM Ground Test Program. (See Figure 4-16.)

- Discrepancies in schedules exist between the NAA Development Test Plan of 30 September 1964 and the GAEC LEM Development Schedule 32A (25 November 1964) (92) (94).

- The latest working schedule, Schedule 35, reflects slippage of three to ten months in the LTA-3 (Structural Test Vehicle), LTA-5 (Propulsion Test Vehicle), and LTA-8 (Thermal Vacuum Test Vehicle) scheduled ground test activities.

- FTA-1 and FTA-2 (flight test articles to demonstrate LEM capability to withstand the Saturn V launch environments) are reported to have been deleted from current planning.

4.7.4 Manufacturing Performance

- The Reaction Control System appears to be a major quality problem due, in part, to poor implementation of quality requirements by the subcontractor.

- Figure 4-17 indicates the trend in quality performance of the prime contractor during the manufacturing cycle. This is measured by determining the defects noted at the prime contractor's facilities per thousand manufacturing man-hours (98).

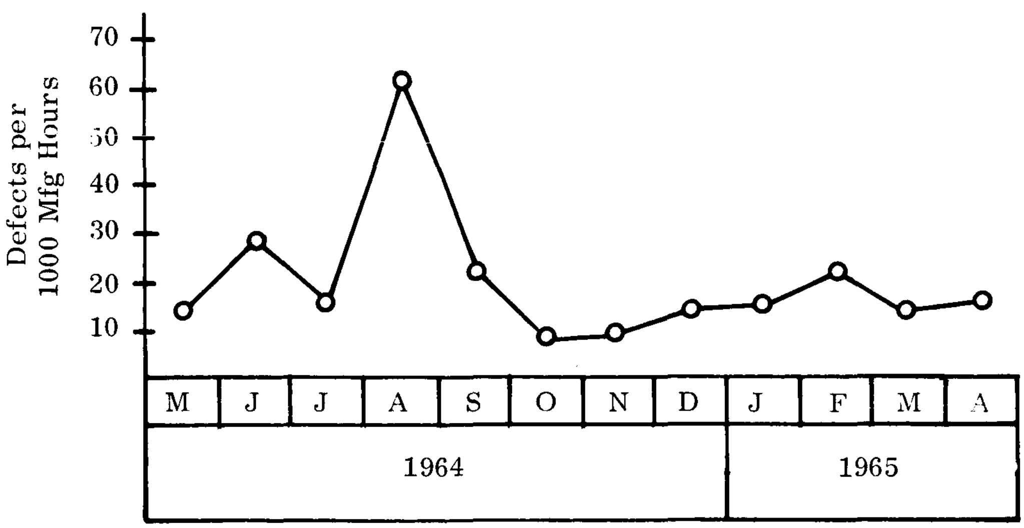


Figure 4-17. LEM Manufacturing Defects

4.8 LAUNCH COMPLEX 39 RELIABILITY

The following reliability activities are planned for Launch Complex 39 Mechanical and Electrical Equipment: Failure Effect Analyses, Criticality Number Determination, Alternate Mode of Operation Plans and Parts Standardization Program.

FEA's

- FEA's have identified 54 items classified as Priority I (capable of causing vehicle loss).

  Systems with Priority I items:

  Inflight Service Arm Retract Systems
  Tail Service Masts
  LOX System
  LH_2 System
  Launcher Support and Holddown Arms
  Fire Protection Firex and Cooling Water Supply
  Hydrogen Flame Detector (Safety Item)
  Hazardous Conditions Monitoring (Safety Item)

4.9 MISSION RELIABILITY ANALYSIS

The Apollo-Saturn 504 Apportionment Analysis presented here is based on the center/contractor documented reliability apportionments for a Manned Lunar Landing Mission shown in Figure 4-18. These data were used to compute a mission success estimate of 0.73 and a crew safety estimate of 0.96*. The reliability goals stated in the Apollo Program Specification (1) are 0.90 and 0.999 for the probabilities of mission success and crew safety respectively. Other inconsistencies in the reliability apportionments are identified in paragraphs 4.9.2, 4.9.3, and 4.9.4.

Reliability apportionments for the Ground Operational Support System and for Ground Support Equipment have not been identified in program documentation.

4.9.1 Mission Success and Crew Safety Estimates. Figure 4-18 contains the mission success reliability apportionments provided by contract work statements, program plans, and contractor documents at the stage/module level. In order to identify program reliability apportionment omissions and inconsistencies, documentation at the subsystem level for these stages and modules was also examined. This examination led to use of the "Reconciled Contract Values," shown in Figure 4-18, for calculation of estimates of the probability of mission 0.73 and the probability of crew safety 0.96.*

*The Method of Computation is described in paragraph 4.9.8.

4.9.2 S-IC Stage Apportionment. The reliability apportionment status for the S-IC stage was obtained from the "Saturn S-IC Reliability Status Report" (104) issued by the Boeing Company. Figure 4-19 shows the apportionments at the major subsystem level, and the apportionments within the subsystem denoted as propulsion-mechanical are provided in Figure 4-20.

The subsystem apportionments listed in Figure 4-19 are consistent with the 0.95 reliability goal for the S-IC stage set by MSFC. However, the stage contractor bases this apportionment on a reliability value of 0.999 for each of the F-1 engines. (See Figure 4-20.)

The MSFC contract (27) specified a reliability goal of 0.99 for each of these engines. Furthermore, the demonstration requirements specified in this contract are based on the 0.99 reliability goal. Thus, there is an inconsistency between the stage apportionments as noted in Figure 4-19 and the F-1 engine contractual goal.

For the purpose of this analysis, a reliability of 0.907 for the S-IC stage was computed based on an apportionment of 0.99 for each F-1 engine and the assumption that the remaining S-IC apportionments remained fixed.

4.9.3 S-II Stage Apportionment. The contractor reliability apportionment status for this analysis comes from two NAA/S&ID documents, "Saturn S-II Reliability Apportionment Report" (83) and "Saturn S-II Reliability Plan" (82), issued during mid-year 1963. Each of these documents contains the stage contractor's evaluation of the apportionment status after several contract change notifications were considered. Figure 4-21 contains data from both these documents.

There is a possible inconsistency in the reliability apportionments for the S-II stage. A 0.95 reliability goal was established by Marshall Space Flight Center (MSFC) (11). Yet the reliability apportionment for the J-2 engines is 0.9504. Thus, the 0.95 goal for the stage cannot be met unless all other equipment has a reliability of 1.0. The contractor reliability apportionment of 0.9155 for the S-II stage was used in this analysis.

4.9.4 S-IVB Stage Apportionment. The reliability apportionment status for the S-IVB stage is displayed in Figure 4-22. This information is taken from a document, "Supplement, Reliability Mathematical Model, Saturn V, S-IVB Stage" (51), issued by the Douglas Missile and Space Division, 15 June 1964. The subsystem apportionments listed in the contractor document are consistent with the 0.95 reliability goal for the S-IVB stage established by MSFC (11). However, a reliability apportionment of 0.993 is listed for the propulsion subsystem. This apportionment is based on a reliability of 0.999 for the J-2 engine (48). The J-2 engine contract (28) specified a reliability goal of 0.99. A reliability goal of 0.941 is obtained when the contractual apportionment of 0.99 for J-2 engine is considered and this value of 0.941 was used in the analyses contained in this report.

4.9.5 Instrument Unit Apportionment. A reliability goal for the IU of 0.992 was specified by the Saturn V Program Development Plan (11). No apportionment below this level was found in the documents reviewed. Reliability documentation scheduled for publication by the major contractor, IBM, is expected to contain further Instrument Unit reliability apportionment information.

4.9.6 Command Service Module Apportionment. The reliability apportionment status for the Block II configuration of the Command Service Module (CSM) were obtained from a MSC letter (32). The mission success and crew safety apportionment contained in the referenced letter are displayed in Figure 4-23.

The mission success reliability apportionments for the subsystems are consistent with the over-all apportionment for the Block II CSM. However, some of the detailed information required to adequately assess the reliability apportionment status is not contained in the referenced documents. For example, the detailed structure of the Integrated Electronic Subsystem of the Block II design is not defined. Apparently this subsystem consists of Guidance and Navigation, Stabilization and Control, Communications, and Instrumentation. Although the Integrated Electronic System concept is to utilize the redundancies of these subsystems (when properly interfaced), this improvement is not reflected by the apportionment numerics, since the apportioned value is very close to that obtained by serial combination.

The crew safety apportionments are provided for information purposes. As discussed in the paragraph 4.9.8, these values were not used in estimating the probability of crew safety for the mission.

4.9.7 Lunar Excursion Module Apportionment. The reliability apportionment status for the Lunar Excursion Module (LEM) was obtained from the Grumman Aircraft Engineering Corporation Quarterly Progress Report (97). These apportionments are based on the Grumman Aircraft Engineering Corporation (GAEC) Reference Mission instead of the Apollo Mission Planning Task Force (AMPTF) Design Reference Mission. An MSC letter (32) states that new apportionments based on the AMPTF Design Reference Mission, as well as recent design changes, will be available later. Figure 4-24 lists the mission success reliability apportionments for the LEM subsystems. The apportionments for the subsystems are consistent with the 0.987 mission success goal for the LEM.

The crew safety apportionments, Figure 4-24, are provided since they were listed in the referenced document. Refer to paragraph 4.9.8 for discussion.

4.9.8 Mission Success and Crew Safety Computation. The mission success and crew safety computations were performed using available apportionment data at the subsystem level. The mission success model consisted of a series network of subsystems structured according to the events necessary for mission success. The abort models were based on the abort ground rules and assumptions specified in Figure 4-25.

The event sequence and operating times used in the modeling and computation process are shown in Figure 4-25. These data structure a nominal Manned Lunar Landing Mission profile into twenty-seven supphases, a level of detail consistent with the apportionment data used. An abort was defined at the termination of each of the mission subphases through event No. 23, "CSM Hard Docking." Aborts beyond this point in the mission were identical to the nominal transearth return path. All events, subphase operating times, and abort data, were drawn from the Reliability Mission Profile (115).

The mission success reliability apportionment over the entire mission time for each element is specified in the referenced documents. The estimate of the probability of mission success was computed by multiplication of these apportionments since the mission success model is a series network.

The estimate of the probability of crew safety was based on the mission success reliability apportionments and a suitable failure distribution for each element over the mission time line.

The probability of crew safety involves basically a determination of the probability that failures fatal to the crew will not occur. Fatal failures can occur either during the nominal mission itself or during an attempted abort.

Suppose that in the latter case, a fatal failure during an abort occurred due to loss of subsystem A. Suppose further that this abort was initiated due to a (non-fatal) failure of subsystem B during the nominal mission. In this situation a degradation of the probability of crew safety has occurred and yet it is not possible logically to say that this fatality was due to subsystem A alone or to subsystem B.

In situations such as this, the allocation of a probability of crew safety to subsystems can be a meaningless statement. Thus, for the calculation of crew safety, the entire system was treated as an integrated whole based on the allocated probabilities of mission success for the various subsystems. The results of previous analyses were used in order to estimate, for each interval of the mission, the probability that a mission failure would be abort enabling. These results were used to weight the probability of abort completion.

Stage/Module	Apollo Program Specification	Ref.	Contract Work Statement	Ref.	Program Plans	Ref.	Contractor Published	Ref.	Reconciled Contract Value
S-IC Stage	.95	1			.95	11	.95	104	.9071*
S-II Stage	.95	1			.95	11	.9155	82	.9155
S-IVB Stage	.95	1	.95	26	.95	11	.95	51	.9414*
Instrument Unit	.99	1			.992	11			.992
Command Service Module	.96	1			.9638	61	.9638	32	.9638
Lunar Excursion Module	.98	1			.984	61	.987	97	.987
Overall Apollo-Saturn (Mission Success)	.90	1			.80**				.73**
Overall Apollo-Saturn (Crew Safety)	.999	1							.96**

* Contractual reliability goals for engines used in calculation for stage

** Calculated from above values

Figure 4-18. Mission Success Reliability Apportionment Status Apollo-Saturn Manned Lunar Landing Mission

SYSTEM OR SUBSYSTEM	RELIABILITY* APPORTIONMENT
Structures	0.9976
Propulsion - Mechanical	0.9805
Support	0.9944
Electrical	0.9921
Flight Control	0.9863
Instrumentation	0.9980
Over-all S-IC Stage	0.9500

*Reference (104) "Saturn S-IC Reliability Status Report"

Figure 4-19. S-IC Stage Reliability Goals for Mission Success, Apollo-Saturn Manned Lunar Landing Mission

SYSTEM OR SUBSYSTEM	RELIABILITY* APPORTIONMENT
F-1 Engines (5)	0.9950**
LOX Delivery	0.9983
Fuel Delivery	0.9966
Retrorockets	0.9981
Fuel Pressurization	0.9938
LOX Pressurization	0.9987
Control Pressure	0.9998
Engines Purge	0.9999
Over-all Propulsion - Mechanical Subsystem	0.9805

* Reference (104) "Saturn S-IC Reliability Status Report"
**The Apportionment of 0.995 for the cluster of five engines implies that each engine is apportioned at 0.999.

Figure 4-20. S-IC Propulsion - Mechanical Subsystem Reliability Goals for Mission Success, Apollo-Saturn Manned Lunar Landing Mission

SYSTEM OR SUBSYSTEM	RELIABILITY APPORTIONMENT
Propulsion, J-2 Engines	0.950400 *
Electrical Control	0.994000 *
Destruct	0.996216 *
Propellant Feed	0.996463 *
Electrical Power	0.997161 *
Propellant Management	0.997169 *
Pressurization	0.997240 *
Structure	0.997629 *
Emergency Detection	0.997836 *
Engine Servicing	0.995774 *
Separation	0.997400 *
Flight Control Electronics	0.998642 *
Engine Actuation	0.998945 *
Thermal Control	0.999000 *
Instruments and Converter	0.999025 *
Telemeter	0.999025 *
Command and Tracking	0.999025 *
Ullage	0.999367 *
Engine Compartment Purge	0.999437 *
Antenna	0.999475 *
Over-all S-II Stage	0.9155**

* Reference (83) "Saturn S-II Reliability Apportionment Report"
**Reference (82) "Saturn S-II Reliability Plan"

Figure 4-21. S-II Stage Reliability Goals for Mission Success, Apollo-Saturn Manned Lunar Landing Mission

SYSTEM OR SUBSYSTEM	RELIABILITY* APPORTIONMENT
Airframe	0.99989
Propulsion	0.99370**
Propellant Utilization	0.99520
Flight Control	0.98500
Auxiliary Power Supply	0.99380
Separation	0.99790
Range Safety	0.99660
Environmental Control System	0.99964
Data Acquisition	0.99380
Electrical	0.99380
Over-all S-IVB Stage	0.95

* Reference (51) "Supplement Reliability Mathematical Model, Saturn V, S-IVB Stage"
**Based on 0.999 Reliability for J-2 Engine

Figure 4-22. S-IVB Stage Reliability Goals for Mission Success, Apollo-Saturn Manned Lunar Landing Mission

SYSTEM OR SUBSYSTEM	MISSION SUCCESS* RELIABILITY APPORTIONMENT	CREW SAFETY* RELIABILITY APPORTIONMENT
Structures	0.999999	0.999999
Heat	0.99995	0.99995
Launch Escape System	0.999972	0.999960
Separation System	0.9999723	0.9999904
Parachute Recovery	0.9999395	0.9999395
Earth Impact and Flotation	0.999995	0.999995
Docking	0.999000	0.9999999
Electrical Power System	0.9953721	0.9999747
Emergency Detection System	0.9999900	0.9999990
Environmental Control System	0.9960268	0.999918
Space Suits	0.9999825	0.9999976
Portable Life Support	0.9999183	0.9999995
Cryogenic Storage	0.9986319	0.9999989
Integrated Electronics	0.9780470	0.9999450
Command Module Reaction Control System	0.9996710	0.9999237
Service Module Reaction Control System	0.9979500	0.999999
Service Module Propulsion System	0.9979282	0.9999055
Over-all Command/Service Module	0.9638512	0.9995131

*Reference (32) MSC Letter

Figure 4-23. Command Service Module (Block II) Reliability Goals, Apollo-Saturn Manned Lunar Landing Mission

SYSTEM OR SUBSYSTEM	MISSION SUCCESS* RELIABILITY APPORTIONMENT	CREW SAFETY* RELIABILITY APPORTIONMENT
Navigation and Guidance and Stabilization and Control	0.9907	0.999875
Descent Propulsion	0.999075	0.999998
Ascent Propulsion	0.999961	0.999976
Reaction Control System	0.99980	0.999935
Electrical Power System	0.99815	0.999916
Environmental Control System	0.999446	0.99982
Communications	0.99992	**
Instrumentation	0.99986	**
Structures	0.99985	0.99998
Pyrotechnic	0.99999	0.99998
Over-all Lunar Excursion Module	0.987	0.9995

* Reference (97) "Grumman Aircraft Engineering Corporation Quarterly Status Report"
**No value given (deemed nonapplicable)

Figure 4-24. Lunar Excursion Module Reliability Goals, Apollo-Saturn Manned Lunar Landing Mission

SUBPHASE NUMBER	EVENT	ELAPSED TIME (HOURS)	ABORT GROUND RULES AND ASSUMPTIONS
1	Lift-Off Hold Down Release	0.0	
2	S-IC Cutoff, S-II Ignite	0.0 (1)	Nominal Launch Escape Tower Abort
3	S-II Cutoff, S-IVB Ignite	0.2	Command Module Reaction Control System Controlled ballistic abort
4	S-IVB Cutoff	0.2 (1)	Service Propulsion System to orbit; Service Propulsion System deboost from earth orbit. Nominal re-entry mode.
5	S-IVB Ignite	3.0	Service Propulsion deboost from earth orbit. Nominal re-entry mode.
6	S-IVB Cutoff	3.1	Service Propulsion direct return abort. Nominal re-entry mode.
7	CSM-LEM S-IVB Separation	3.4	Same as Subphase 6
8	S-IVB Jettison	3.8	Service Propulsion System backed up by Lunar Excursion Module descent engine direct return abort
9	Service Propulsion Ignite	5.1	Same as Subphase 8
10	Service Propulsion Cutoff	5.1 (1)	Same as Subphase 8
11	Service Propulsion Ignite	55.5	Same as Subphase 8
12	Service Propulsion Cutoff	55.5 (1)	Same as Subphase 8
13	Service Propulsion Ignite	63.3	Same as Subphase 8
14	Service Propulsion Cutoff	63.3 (1)	Same as Subphase 8
15	Service Propulsion Ignite	64.2	Same as Subphase 8
16	Service Propulsion Cutoff	64.4	Same as Subphase 8
17	Begin Hohmann Transfer	68.4	Re-docking using either Command Service Module or Lunar Excursion Module. Service Propulsion backed up by Lunar Excursion Module descent

Figure 4-25. Profile Used for Reliability Apportionment

SUBPHASE NUMBER	EVENT	ELAPSED TIME (HOURS)	ABORT GROUND RULES AND ASSUMPTIONS
			engine on transearth return. Nominal re-entry mode.
18	End Hohmann Transfer	68.4 (1)	Lunar Excursion Module ascent engine abort. Re-docking with either Command Service Module or Lunar Excursion Module. Service Propulsion System Transearth return. Nominal re-entry mode.
19	Begin Powered Descent	69.4	Same as Subphase 18
20	End of Minimum Lunar Stay	71.6	Same as Subphase 18
21	LEM Liftoff	104.3	Lunar Excursion Module ascent engine abort with Command Service Module rescue. Re-docking using either Command Service Module or Lunar Excursion Module. Service Propulsion System transearth return. Nominal re-entry mode.
22	Ascent Engine Shutdown	104.4	Same as Subphase 21
23	CSM-LEM Hard Docking	105.6	Same as Subphase 21
24	Service Propulsion Ignite (Burn phases combined)	109.1	
25	Service Propulsion Cutoff	109.2	
26	CM-SM Separation	198.0	
27	Retrieval Crew Rescue	198.7	

(1) Time increments for these subphases are less than one-tenth of an hour. For reliability analysis purposes, all times have been rounded to the nearest tenth of an hour.

Figure 4-25. Profile Used for Reliability Apportionment (Cont.)

SECTION 5: APOLLO RELIABILITY AND QUALITY ASSURANCE PROGRAM MANAGEMENT

5.1 GENERAL

This section presents the status of NASA reliability and quality assurance program activities necessary to establish the broad management base required to plan, implement, and control the Apollo Reliability and Quality Assurance Program. The program is viewed from the standpoint of Plans and Status Reporting, Program Audits, and Technical Integration of significant reliability and quality assurance activities.

5.1.1 Accomplishments. Effective planning, management, and control of the Apollo Reliability and Quality Assurance Program requires clearly defined goals, schedules, and review procedures. Accomplishments have been:

- An Apollo Reliability and Quality Assurance Program Plan (2) (Coordination Draft) was issued.
- Implementation of coordinated technical activities by the Apollo Program Office and MSF Centers has been initiated for Failure Reporting Systems, Training and Motivation, Parts and Materials Program, and Quantitative Reliability Analysis.
- A policy for Apollo Program Single Point Failure Analysis has been issued in draft form, and plans are being prepared for total integrated implementation of the policy.
- The development of a compatible family of reliability analysis models at the program, center, and contractor levels has been initiated.

5.1.2 Problems. Continued intensive effort is necessary to implement a total system to assure cohesive direction and evaluation of reliability and quality assurance activities. The following are considered problems impeding effective implementation of an Apollo management system:

- At this time, a basic plan for reliability and quality assurance implementation has not been fully established because control documentation in the form of Project Development Plans and Reliability and Quality Assurance Program Plans has not been issued by all NASA organizations.
- Program audits by the Apollo Reliability and Quality Assurance Office to determine adequacy of implemented reliability and quality activities at MSF Centers have not been performed or scheduled.

- Status reporting procedures have not been implemented to the degree required for effective program evaluation and measurement.

5.2 PLANS AND STATUS REPORTING

5.2.1 Program/Project Development Plans. Apollo Program and MSF Center reliability and quality policies and requirements are now in place as contained in the Apollo Program Development Plan issued by the Apollo Program Office, and Project Development Plans issued by each of the Apollo Project Offices at MSFC.

5.2.2 Reliability and Quality Assurance Plans. Apollo Reliability and Quality Assurance Offices in the Apollo Program Office and at the MSC Centers have issued, or are preparing, Reliability and Quality Program Plans as shown in Figure 5-1.

All plans must be completed to comply with Project Development Plan requirements and to establish definitive schedules for reliability and quality assurance accomplishment in consonance with approved program schedules.

PLAN TITLE	COMMENTS
Apollo R&QA Program Plan	Coordination draft issued in May 1965. Center coordination to be completed July 1965. Plan to be approved August 1965
MSFC R&QA Program Plan	Draft issued 4 May 1965.
MSC Reliability Program Plan	Approved by center management and issued Aug 1964
MSC Quality Program Plan	Approved by center management and issued Feb 1965
KSC R&QA Program Plan	Approved by center management and issued Dec 1964. The plan includes policy and responsibility definition.

Figure 5-1. Program Planning Summary

5.2.3 MSF Center Status Reporting. Status reports essential for measurement and control of the Apollo Reliability and Quality Assurance Program are included as requirements in the Apollo Reliability and Quality Assurance Program Plan (2). Procedures currently in effect are not uniform and reliability and quality assurance information reported to date has been generally incomplete.

At MSFC, the Engines Project Office and the Saturn V Project Office issue reliability and quality assurance status information. The Engine Project Office reliability and quality assurance information is included as part of the over-all "Engines Technical Progress Report" issued quarterly (24). The Saturn V Project Office issues monthly reports devoted solely to reliability and quality assurance (25). At MSC, ASPO prepared an over-all project technical status report for the period ending 31 December 1964 (34). This report, issued in May 1965 and given limited distribution, included a section on reliability and quality assurance status.

It is anticipated that adoption of the Apollo Reliability and Quality Assurance Program Plan (2) will clarify status reporting procedures resulting in more meaningful, informative, and timely reports.

5.3 PROGRAM AUDITS

The Apollo Reliability and Quality Assurance Program Plan (2) requires that the Apollo Reliability and Quality Assurance Office audit the activities and performance of MSF Centers Reliability and Quality Assurance Offices. To date, no formal audits have been made, nor are any scheduled.

Meanwhile, MSF Centers have been performing scheduled audits of prime system contractors and selected subcontractors. A summary of prime contractor audits accomplished and scheduled by MSFC and MSC is shown in Figure 5-2. Implementing divisions at KSC are performing reliability and quality audits of facility and GSE contractors, but schedules are not available.

5.4 TECHNICAL INTEGRATION

Program wide coordination of selected reliability and quality assurance activities is being accomplished by teamwork of the Reliability and Quality Offices at the centers and the Apollo Reliability and Quality Assurance Office. This coordination has been directed at those areas where integrated effort will provide maximum program benefit.

5.4.1 Failure Reporting System. Each of the Manned Space Flight Centers and their contractors have instituted closed-loop failure reporting systems that provide for recording, analysis, and correction of failures. These systems vary significantly, each being designed to fit the individual needs of the user. Data systems have been established to edit, code, process, store, and retrieve the failure data generated by the failure reporting system.

A number of improvements are needed in the failure reporting and corrective action systems to assure that the requirements of the Apollo Reliability and Quality Assurance Program are met. In some cases, action is already started on these improvements.

The most significant of these needed improvements are:

a. Emphasis on the retrieval of information from the data system in a form most useful to program management. Effort has already been initiated to provide periodic failure summary information for the Apollo Program Office. However the need exists at all levels of management for summary reports on significant failure trends, corrective action, and present equipment status. More uniformity in classification of failures is needed to permit logical failure summaries.

SPACE SYSTEM	PC	1965											
		J	F	M	A	M	J	J	A	S	O	N	D
S-IB Stage			R▲							Q△			
S-IC Stage	Q▲		R▲						Q△				
S-II Stage	Q▲							Q△	R				
S-IVB Stage	Q▲				Q▲					R△			
F-1 Engine	Q▲R								Q△				
H-1 Engine	Q▲R												
J-2 Engine	Q▲R								Q△				
Instrument Unit	Q▲								Q△[1]		Q△[2]		Q△[3]
Lunar Excursion Module	Q▲									R△		Q△	
Guidance and Navigation	Q▲							R△	Q△				
Command and Service Module	Q▲										Q△	R△	
Space Suit													

Symbols: PC - Previously Complete
△ - Scheduled Completion Date
▲ - Actual Completion Date
R - Reliability Audit
Q - Quality Audit

1 - Audit Owego Facility
2 - Audit Teterboro Facility
3 - Audit Huntsville Facility

Figure 5-2. Summary of MSC Center Reliability and Quality Audits

b. The data systems must incorporate procedures for relating failures of hardware to the exposure of hardware; that is, the failures encountered against the opportunity for failure. This relationship is essential to the evaluation of failure rates and the assessment of hardware reliability.

c. Activity has been initiated to establish rapid, intelligible communications between data systems, both center to center, and center to contractor. In accomplishing this the physical method by which data is exchanged must be resolved. The most frequent method being implemented presently is exchange by magnetic tape.

5.4.2 Training and Motivation

Training. Regularly scheduled Reliability and Quality Assurance Training programs have been implemented by the Apollo Reliability and Quality Assurance Office and MSF Centers. Specific training courses are generally prepared and presented by contractor personnel at the request of individual NASA Project Managers. For example, SPACO Corporation, ARINC Research, and Boeing Aircraft Company have prepared and presented courses at MSFC; and General Electric Company has prepared and presented Reliability and Quality Surveyors Courses for the Apollo Reliability and Quality Assurance Office.

Training courses being offered by the Apollo Reliability and Quality Assurance Office and MSF Centers are shown in Figure 5-3.

Motivation. In the field of reliability and quality motivation, MSFC is continuing development of a Manned Space Flight Awareness Program, and progress is being made at MSC and KSC to implement awareness programs. Further coordination of these motivation programs should result in increased impact on the Apollo Program for less total effort.

Motivation programs currently reported as being implemented by Apollo contractors include:

Boeing Company	Zero Defects
Bendix Corporation	Manned Flight Awareness Program
Electronic Communications Inc.	Manned Flight Awareness Program
IBM	Manned Flight Awareness Program
General Electric Company	Zero Defects
North American Aviation	PRIDE
Chrysler Corporation	CARE

5.4.3 Parts and Materials Program. MSF Centers have established programs to ensure the selection and application of reliable parts, materials, and components. A formal Parts and Materials Program was initiated at MSC in February 1965. The program will provide data and information on parts and materials for spacecraft applications and will provide information for the generation of a Parts and Materials Failure Index.

Implementing divisions at KSC have also initiated some Parts and Materials Program activities, such as Parts Inventory Lists and Parts Standards. MSFC is continuing their established parts program and, in addition, was designated lead center for the dissemination of parts information (7). The Parts Reliability Information Center (PRINCE) was designated by MSFC to be the central control agency for this parts information activity.

Course Title	Remarks
High Reliability Soldering (Certification and Recertification)	Offered at KSC, MSC, and MSFC
NASA Quality Requirements The NASA Plant Representative Reliable Electrical Connections (Module Welding) Potting, Molding, Encapsulation, and Conformal Coating Automatic Checkout System Orientation Standard Acceptance Test or Launch Language Automatic Checkout Control Techniques Optical Alignment (Basic) Optical Alignment (Advanced) Component Analysis Cleaning Control and Fluid Analysis High Pressure Systems Manufacturing and Tooling Reliability Engineering	Offered at MSFC for appropriate NASA personnel from all NASA locations.
Training Seminar for Reliability Surveyors	Offered at Daytona Beach, Florida for NASA and Contractor personnel. Twenty-seven personnel participated during reporting period.
Training Seminar for Quality Surveyors	Offered at Daytona Beach, Florida for NASA and Contractor personnel. Forty personnel participated during reporting period.

Figure 5-3. NASA Reliability and Quality Assurance Training Courses

5.4.4 Single Point Failure Analysis. Single Point Failure Analysis policy for the Apollo Program has been issued in draft form by the Associate Administrator for Manned Space Flight. In response to this policy, areas of program responsibility have been assigned to each Directorate in the Apollo Program Office. The Apollo Reliability and Quality Assurance Director has been assigned responsibility for the space vehicle, launch complex, associated GSE, and over-all coordination responsibility for all five areas of Single Point Failure Analysis and review for the Apollo Program. Each Apollo Program Office Directorate in the Program Office is preparing an action plan based upon assigned responsibilities, to be consolidated into an over-all Single Point Failure Analysis Plan for the Apollo Program.

The Apollo Reliability and Quality Assurance Office Single Point Failure Analysis Action Plan defines an approach and presents guidelines for accomplishing an analysis study. Schedules have been proposed for reports and study completion as follows:

Interim report by MSF Centers to Apollo Reliability and Quality Assurance Office	- 30 July 1965
Saturn IB portion of study complete	- 15 September 1965
Saturn V portion of study complete	- 22 November 1965

Failure Mode Effect and Criticality Analyses presently being performed by MSF Centers are described below:

MSFC requires criticality ranking by criticality number in accordance with their guideline document (21). The procedure given in that document has been in effect on MSFC contracts over the last three years. As a result, Failure Mode Effect and Criticality Analyses with numerical criticality rankings exist, or are being prepared for MSFC Apollo-Saturn hardware.

MSC requires criticality ranking by class (30). The three classes are:

a. Failures resulting in subjecting crew beyond emergency limits.

b. Failures resulting in abort.

c. Failures resulting in lesser accidents.

Most of the MSC Apollo hardware Single Point Failure Analyses are currently incomplete or preliminary.

KSC has developed and is utilizing a procedure (41) for numerical criticality rankings. GSE failures are classified according to their effect on:

a. Loss of vehicle or stage.

b. Launch scrub.

c. Countdown delay.

5.4.5 Quantitative Reliability Analysis. A plan for Apollo Program Quantitative Reliability Analysis was presented at the MSF Program Status Review Meeting on 22 March 1965 by the Apollo Reliability and Quality Director. This plan is built on a concept that each MSF Center and Contractor will prepare an effective reliability model reflecting the level of detail necessary for managing its own program. The mission model plan illustrated in Figure 5-4 indicates a need for four levels of modelling activity for effective reliability analysis.

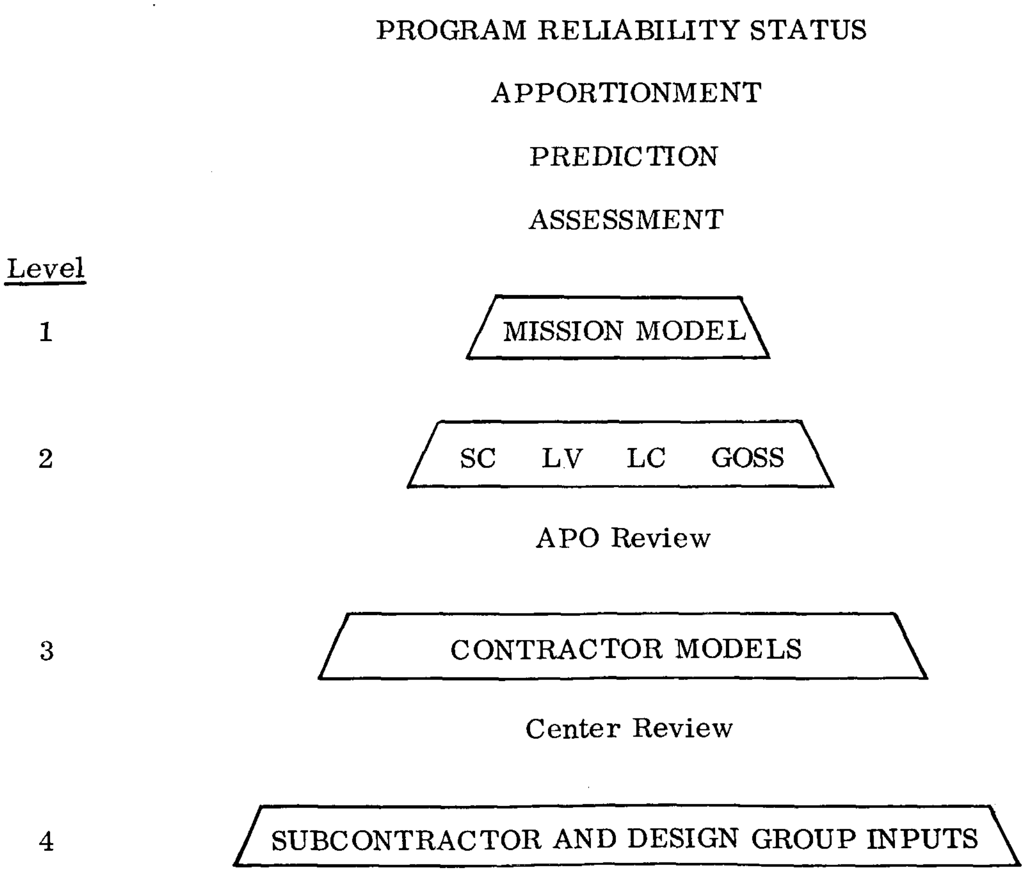


Figure 5-4. Plan for Mission Model

A coordination meeting was held on 11 and 12 May 1965 at MSC to familiarize MSF Center and Contractor personnel with this Quantitative Analysis Plan. It was agreed by those attending the meeting that the analysis approach outlined could be implemented without serious impact on contractors (10).

Two major problems (10) revealed at the meeting were:

a. launch availability analysis is lagging

b. there is a need for early determination of reliability mission profile.

Present lack of a common mission profile permits misinterpretation of the various reliability estimates and makes the analysis of crew safety quite difficult. The development of a compatible family of reliability models within the Apollo Program is dependent upon the utilization of a common mission by contractors and MSF Centers at all levels.

As a result of the meeting, "Guidelines for the Structure and Outputs for Apollo Reliability Models" and "Guidelines for Conduct of Systematic Reviews of Apollo Reliability Models" were prepared (10). Further, initial program implementation reviews were scheduled for Apollo Reliability and Quality Assurance Office, and MSFC, MSC, and KSC.

Similarly, a schedule for review of space vehicle reliability analysis inputs by MSF Centers was established (10) as follows:

		Review Date	
System Element	Cognizant Center	Apollo-Saturn 201 Configuration	Apollo-Saturn 504 Configuration
SC	MSC	7/65 - 9/65	8/65
LEM	MSC	7/65 - 9/65	11/65
G&N	MSC	7/65 - 9/65	7/65 - 9/65
S-IC	MSFC	NA	9/65
S-IB	MSFC	7/65	NA
F-1	MSFC	NA	8/65
H-1	MSFC	7/65	NA
S-II	MSFC	NA	9/65
J-2	MSFC	7/65	8/65
S-IVB	MSFC	7/65	8/65
IU	MSFC	7/65	8/65
GSE	MSFC	8/65	11/65

5.4.6 Apollo Program Reliability and Quality Guidelines. A partial summary of Apollo Office Reliability and Quality Assurance standards, procedures, and guidelines issued or in the MSF Center coordination phase during the period of this report is shown by Figure 5-5.

Title	Status
Guideline for Preparation and Maintenance of Equipment Logs	Draft phase; scheduled for center review in September 1965
Guideline for Failure Mode Effect and Criticality Analysis	Draft phase; scheduled for center review in September 1965
Interpretation and Selective Application of Reliability Provisions of NPC 250-1	Draft completed; scheduled for center review in August 1965
Principles of Electromagnetic Compatibility (Manual for EMC Awareness Course)	Draft completed; scheduled for center review in August 1965
Quality Audit Handbook	Transmitted to Apollo Program Office for publication
Preparation of Contractor's Quality Program Plan	Coordination with centers complete. Ready for publication
Preparation of Supplier's Inspection Plan	Coordination with centers complete. Ready for publication
Standard for Apollo Metrology Program	Center comments on final coordination draft scheduled 30 June 1965
Policies and Procedures for Material Review Board Activities	Center comments on final coordination draft scheduled 30 June 1965
Identification for Traceability Standard	Distributed to centers for review and comment in May 1965
Summary of Problems with Electrical Connectors and Insulated Wire in the Aerospace Industry, TM x-1083	Published in March 1965
Cleanliness Standards and Contamination Control	Distributed to centers for review and comment in May 1965
Process Specification for Radiography	Distributed to centers for review and comment in May 1965

Figure 5-5. NASA Reliability and Quality Assurance Guidelines

5.4.7 Crew Reliability Studies. The Apollo Reliability and Quality Assurance Office is providing continuing support to the OMSF Contract NASw-1187 with the Martin Company in Baltimore for studies on crew reliability. The first crew of three Department of Defense test pilots was scheduled to start the seven-day lunar landing mission simulation on 25 June after five weeks of training. Two other teams of three pilots each will follow. In order for the outputs of this study to have maximum value to the Apollo Program, support has been given, thus far, in reviewing the Statement of Work and in consulting on the type and form of the data to be recorded and analyzed. Types of data to be collected include (1) how well the crew performs switching functions and (2) how well the crew navigates and maneuvers the spacecraft and the amount of fuel used.

APPENDIX A
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APPENDIX B
LIST OF ABBREVIATIONS AND CODES

ACE - Acceptance Checkout Equipment
ACS - Automatic Control System
AM - Amplitude Modulation
AMPTF - Apollo Mission Planning Task Force
APO - Apollo Program Office
APS - Auxiliary Propulsion System
ASPO - Apollo Spacecraft Project Office
ATR - Apollo Test Requirements
BP - Boiler Plate Spacecraft
CCSD - Chrysler Corporation Space Division
CM - Command Module
C/O - Checkout
COFW - Certification of Flight Worthiness
CSM - Command/Service Module
DOD - Department of Defense
EBW - Exploding Bridge Wire
ECS - Environmental Control Subsystem
EDS - Emergency Detection Subsystem
E/E - Electrical/Electronic
EI - End Item
ELS - Earth Landing System
EPS - Electrical Power Subsystem
ESE - Electrical Support Equipment
ETR - Eastern Test Range
F/A - Fabrication/Assembly
FEA - Failure Effects Analysis
FM - Frequency Modulation
FMEA - Failure Mode Effects Analysis
FR - Failure Report
FRT - Flight Readiness Test
GA - Government Agency
GAEC - Grumman Aircraft Engineering Corporation
GFE - Government Furnished Equipment
GN_2 - Gaseous Nitrogen
G&N - Guidance and Navigation
GOSS - Ground Operational Support System
GSE - Ground Support Equipment
GSFC - Goddard Space Flight Center
IBM - International Business Machines Corporation
IMCC - Integrated Mission Control Center
IMU - Inertial Measurement Unit
IU - Instrument Unit
K - 1000 pounds
KSC - Kennedy Space Center
LC - Launch Complex
LCC - Launch Control Center
LEM - Lunar Excursion Module
LES - Launch Escape System
LH_2 - Liquid Hydrogen
LJ - Little Joe Launch Vehicle
LOR - Lunar Orbit Rendezvous
LOX - Liquid Oxygen
LTA - LEM Test Article
LUT - Launcher-Umbilical Tower
LV - Launch Vehicle
MCC - Mission Control Center
MILA - Merritt Island Launch Area
MLL - Manned Lunar Landing
MMH - Monomethylhydrazine
MRB - Material Review Board
MSC - Manned Spacecraft Center
MSF - Manned Space Flight
MSFC - Marshall Space Flight Center
MSFN - Manned Space Flight Network
NAA - North American Aviation, Inc.
NASA - National Aeronautics and Space Administration
NMI - NASA Management Instruction
N_2O_4 - Nitrous Oxide
NPC - NASA Publication Control (Number)
ODOP - Offset Doppler Electronic Tracking System
OMSF - Office of Manned Space Flight
PAD - Project Approval Document
PAM - Pulse Amplitude Modulation
PCM - Pulse Code Modulation
PDP - Program/Project Development Plan

PERT - Program Evaluation and Review Technique
PM - Phase Modulation
P/M - Propulsion/Mechanical
P/N - Part Number
QVVT - Qualification Verification Vibration Test
RCS - Reaction Control System
R&D - Research and Development
RF - Radio Frequency
RFI - Radio Frequency Interference
RFP - Requests for Proposals
R&Q - Reliability and Quality
R&QA - Reliability and Quality Assurance
S/C - Spacecraft
SCS - Stabilization and Control System
SLA - Spacecraft-LEM-Adapter
SM - Service Module
Spec - Specification
SPS - Service Propulsion System
TOPS - Thrust OK Pressure Switch
UDMH - Unsymmetrical Dimethylhydrazine
UHF - Ultra High Frequency
ULD - Unit Logic Device
VAB - Vertical Assembly Building
VHF - Very High Frequency